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July 2006

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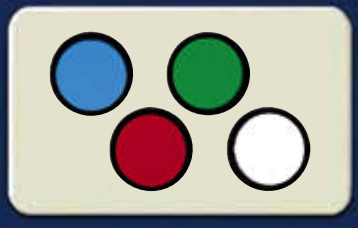

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ON THE COVER

What have scientists learned from the Cassini mission? The moon Hyperion looks like a battered sponge. Phoebe may be a captured comet. Enceladus hosts icy geysers. Titan still has much to tell. Imaging team member Alfred S. McEwen reviews highlights from Cassini's mission on page 30.

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Astronomy

Observing, telescopes, origin and fate of the cosmos

july 2006

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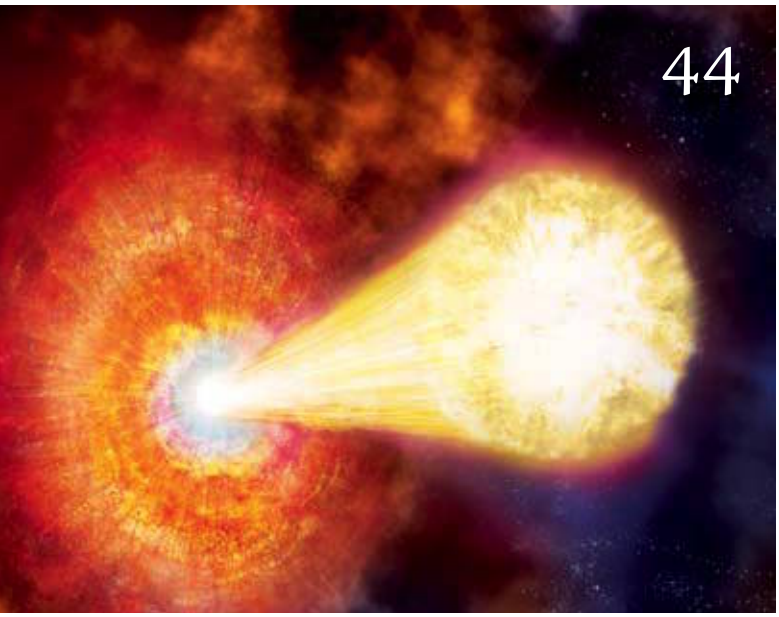

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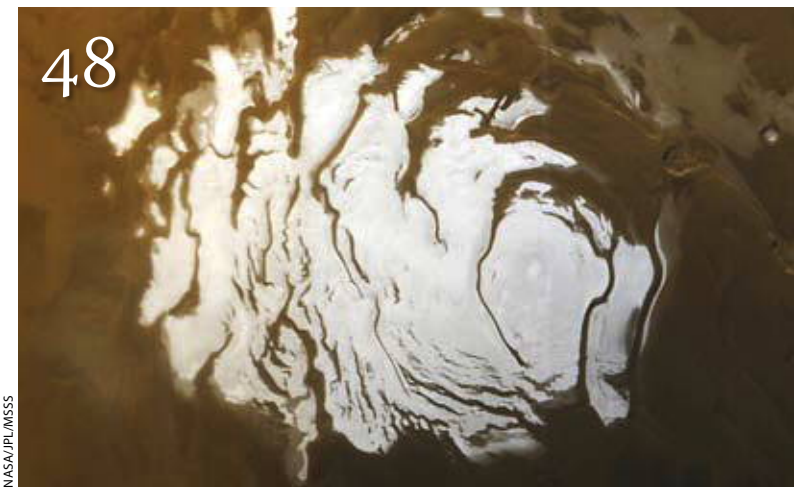

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MIKE SIMMONS

BY DAVID J. EICHER

Where does it all lead?

Until recently, cosmologists didn't know

anything but the basics of the story of the universe. They would have been hard-pressed to give you the details of the most basic life questions: How old is the universe? How big is it? How large? What will happen to the universe when it all ends?

Over the last few years, astronomers have achieved a good handle on the big questions. But the story of what will ultimately happen to the cosmos is still a murky one. Moving toward a satisfying answer requires understanding what makes up the universe and what's happening with those components now. This is the focus of James Trefil's story "Where is the universe heading?" on page 36. Trefil, a physicist at George Mason University and a member of *Astronomy*'s editorial advisory board, describes the possibilities of the universe's fate.

Will the cosmos keep expanding forever, going colder and darker as time rolls on, ending with a whimper hundreds of billions of years from now? Astronomers term this scenario the Big Chill.

Or will a "Big Crunch" occur in which the universe falls back on itself in an explosive rebirth, generating a new and catastrophic Big Bang? For all the lurid details, see Trefil's entertaining (and brilliantly illustrated) story.

Once upon a time, just a few years ago, another mystery confounded astronomers. Gamma-ray bursts — short, unbelievably energetic explosions scattered around the sky — were unexplained. Now, a NASA satellite called Swift has solved the puzzle of what causes one type of these events, called short gamma-ray bursts. In a compelling detective story, science writer Robert Zimmerman explains the recent findings in "Witness to cosmic collisions" on page 44.

Back in our solar system, the big news of the moment continues to focus on Saturn. Two years into its mission, NASA's Cassini spacecraft still orbits the ringed planet and is taking data furiously, giving us our best-ever looks at Saturn and its enigmatic moons. Alfred McEwen, a member of the Cassini Imaging Team, provides a substantial update on Saturn's new worlds in "Cassini unveils Saturn" on page 30.

The most amazing recent finds include the geyser-like fountains on the moon Enceladus, the moon Hyperion's weird, spongy structure, new forms found within Saturn's rings, and icy volcanoes and hydrocarbon lakes on Titan.

Planetary science is alive and well on Mars, too, where most of NASA's energy is still focused, as the agency pursues answers about water and possibly life. This month, Associate Editor Francis Reddy delivers a look at some strange, little-known forms on Mars astronomers are calling "spiders."

These dark, branching patterns visible near the Red Planet's south pole are as yet unexplained. But in "Spiders on Mars" (page 48), Reddy describes how these strange forms, which change appearance on relatively short timescales, may be artifacts in the ice of escaping carbon-dioxide gas. It's a fascinating story not yet told outside the world of professional planetary-science papers.

Yours truly,

David J. Eicher
Editor

Astronomy

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Read and discover

After reading Michael E. Bakich's "Catch Mercury at its best" (February 2006), I went outside to look for the planet but did not see it, despite a clear sky. Because I live in downtown Denver, I figured the Front Range Mountains must have blocked my view. A few days later, I saw Mercury just above the mountain peaks to the west. I took pictures of it and sent them to some web sites. One picture appeared on Spaceweather.com, NASA web sites, and a couple dozen blogs.

Seeing my photo on NASA web sites was a great experience. The picture inspired my family and friends to look for Mercury, too. **— JEFFREY BEALL,** DENVER

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Thanks to *Astronomy*'s customer sales and service team for providing all the back issues I missed when hurricane Katrina passed over our house in Mississippi and during our subsequent move to Ohio. I received all of the missing issues. **— LAWRENCE SOWER,** SPRINGBORO, OHIO

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BURSTING WITH CURIOSITY

If a gamma-ray burst occurred 440 million light-years away, did it happen 440 million years ago and the light from the event is just now reaching us? — MARK TURNER, CARSON CITY, NEVADA

***Correct! The burst occurred 440 million years ago, and its energy is just now reaching telescopes on Earth.* — FRANCIS REDDY,** ASSOCIATE EDITOR

A FEW DAYS after his first attempt to find Mercury failed, Jeffrey Beall searched again and found the planet staring back at him from above the Front Range mountains outside Denver. JEFFREY BEALL

Rainbow connections

The two-page spread "The universe across the spectrum" (March 2006) helped me gain a better understanding of the relationships among various spectra. **— PAUL E. MITCHELL,** GLEN SPEY, NEW YORK

Renaissance learning

What do extraterrestrials (ET), time travel, and whale sharks have to do with teaching Spanish? My students asked the same question when I showed them the February 2006 *Astronomy*. We spend a lot of time on different aspects of communication, including assumptions we make about sending and receiving messages — so they had little trouble appreciating Bob Berman's "If ET talks back." They also enjoyed the time-travel article "Is time on our side?"

But then we got to the news story about sharks, "Astronomy and biology unite." Identifying and tracking whale sharks by using pattern-recognition tools developed for astronomers exemplifies why people should read about discoveries outside their own fields. Astrophysicist Zaven Arzoumanian made a whopper of a connection between two seemingly unrelated fields and helped make the world a better place — at least for whale sharks. The message: Keep exploring! **— ELOISE ARIZA-RODRIGUEZ,** CAIRO AMERICAN COLLEGE, EGYPT

Poster of stars

Congratulations on the excellent April issue and a most informative center poster on the "Secret lives of stars." Thank you so much for putting together a useful reference that amateurs can keep and understand. You have helped to clarify a changing and difficult subject. **— DONALD CRAIG, JR.,** INDIANAPOLIS

Hot topic

Francis Reddy's March 7 news article "Titan, Mars methane may be on ice" on Astronomy.com suggests that climate change may be occurring throughout the solar system, not just on Earth. Instead of "global warming," we may have "globes warming." **— ERIC NILSEN,** MANCHESTER, MISSOURI

Correction

Contrary to what was published in the May 2006 New products (page 92), Meade Instruments Corporation's Series 4000 Eyepiece/filter set costs $199 when purchased with a Meade telescope. When purchased separately, the set costs $299.
— *ASTRONOMY* EDITORS

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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BY BOB BERMAN

Quantum weirdness

Quantum mechanics deals with

subatomic particles, so it may seem far removed from astronomy. But those little critters comprise the entire universe, and they're all tied together. Quantum theory seethes with wonderful head-scratchers. The weird stuff includes:

1. The famous double-slit experiment that shows interference patterns, even when only one electron flies through the apparatus at a time. What interferes with it?
2. Tiny particles go from point A to B, but they take none of the routes available to them. They do something we can't imagine. Electrons doing such impossible things are in a state of superposition.
3. The more accurately you pin down a particle's position, the less you know about its motion. This is known as Heisenberg's uncertainty principle — proposed in 1927 by German physicist Werner Heisenberg. Other pairs of similarly incompatible properties exist as well.

These are facts. Problems arise only when we try to make sense of them altogether. Probably the best-known view is the Copenhagen Interpretation, which sprang mostly from the fertile minds of Heisenberg and Neils Bohr in the 1930s.

They believed the inability to know both an electron's motion and position simultaneously was not just a measurement problem. Instead, the issue was far more fundamental: An electron does not *have* a position or a motion unless someone looks at it!

The idea goes like this: Every solid object is made of energy and has a wave nature. Small-particle waves are well understood, and their wave function collapses when they are disturbed. Only then can that particle actually exist in a specific spot. What makes a particle's wave function collapse? To measure it, you have to hit it with something like light, and that instantly does the job. But these guys went further and said merely learning about the electron triggers the collapse. *Knowledge* alone collapses a wave function.

Wait, it gets worse. From there, it was only a short mad stroll to the increasingly accepted (but still minority) notion that no objective universe exists. Observations *are* the cosmos. Without your mind, things don't exist — certainly not in their present forms.

Not happy with that? Then consider the most popular alternative, the Many Worlds Interpretation (MWI), accepted by such luminaries as Stephen Hawking. The MWI presumes countless realities in addition to the world we know.

> Without your mind, things don't exist.

Every time you make any choice in life, or perform any sort of experiment with more than one possible outcome, all outcomes occur, each in a different world. We are aware only of the world that contains the result we have seen.

The MWI avoids the "spooky action at a distance" of Copenhagen and reasserts "realism," or an objective reality. Contradictions, superpositions, and wave-collapse choices vanish because only one outcome inhabits the world we know. You occupy one universe. Other universes exist in which another "you" who once toyed with the notion of studying art instead of law did, indeed, move to Tuscany and marry that girl you once met on a bus.

Today, MWI is widely embraced, but I suspect we might soon swing back toward Copenhagen because entangled-particle experiments support "non-locality."

To understand this theory, we should reboard that carnival ride we took 2 years ago in "Theory chaotic" (July 2004). In brief, bits of light or matter get created at the same time and fly off in different directions. But they are entangled, meaning they share a wave function because of their simultaneous births. So, if one particle or photon is observed, measured, or interfered with in any way, its twin instantaneously knows this happened, and its own wave function collapses.

Result: If you measure a particle and learn it spins clockwise, its twin suddenly leaves its blurry "anything's possible" reality and exhibits an opposite spin. This happens instantly, even if a billion light-years separate the pair. It also works with groups of particles. Objects aren't independent of the rest of the universe, and quantum news travels infinitely faster than light. Wild stuff, and true: It's been repeatedly confirmed since 1997.

Does this make your head spin? Maybe that's why mine has started to spin, too, the opposite way.

But perhaps we needn't even choose between Copenhagen and MWI. Maybe quantum's paradoxes arise from some as-yet-undiscovered interaction between the experimental apparatus and the particles. Or unknown phenomena may be at play.

If we're willing to say, "Maybe this theory is incomplete," that might keep our head-spinning to a minimum, for now.

In the meantime, we can thank — or blame — Werner Heisenberg for appearing here in our world, rather than in next-door reality 8766.

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The Reviews are In: "A telescope mount for the 21st century"
***Astronomy* magazine, November 2005**

- "The Star Book is so easy to operate it flirts with user-interface perfection ... ."
- "As it stands now, the Sphinx is by far the easiest-to-use go-to mount."
- "Those interested in imaging should give this mount consideration."
- "The Sphinx is an extraordinary value because this amount of periodic error is normally encountered only in mounts 4 or 5 times its cost."
- "More good news: The mount is terrific."
- "To its credit, the screen worked well even at low temperatures — I subjected it to a test at -15° Fahrenheit (-26° Celsius) one night... ."

Recommended Accessories

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Aluminum Case

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BY GLENN CHAPLE

Off to Vermont

Let's see, do I have my binoculars?

Check. Telescope? Check. Tent? Check. Sleeping bag? Check. Teddy bear? Now, where the heck did I put my … Oh, hi! I'm just getting ready for my pilgrimage to Breezy Hill in rural Vermont for this year's Stellafane Convention. Each year, more than 1,000 amateur astronomers converge on this hallowed ground for a weekend of astronomy and telescope-making. Many, myself included, will camp in the fields and clearings near the pink Stellafane clubhouse and observe under a cloudless (we hope!) Green Mountain sky. Whether or not the weather cooperates, there's always the pleasure of being in the company of so many astronomy enthusiasts.

Stellafane's rich history sets it apart from other astronomy conventions. In the 1920s, telescope-making got started in this area of the United States. In those days, commercially made telescopes often were beyond the financial grasp of astronomy enthusiasts. Making a reflecting telescope — by grinding and polishing the main mirror, then assembling the scope from locally available parts — was often the would-be telescope owner's only option.

In 1920, sixteen people from Springfield, Vermont, attended a telescope-making class under the tutelage of Russell Porter. That class evolved into an astronomy club (Springfield Telescope Makers), and then into a convention — Stellafane. *Scientific American* reported on their telescope-making innovations, and the rest is history.

The Dobsonian mount's debut in the late 1970s made telescopes more affordable. Still, the telescope-making bug lives on. Perhaps it's the allure of unlocking the universe's wonders with a tool made from your own hands. Every amateur astronomer should at least try to construct a homebuilt telescope during her or his life, whether from "scratch" or from a kit.

Making a telescope from the ground up can be a daunting task. I know, because in my cellar is an incomplete 6-inch mirror I began grinding back in 1970! I started out alone, immediately ran into problems, and gave up. I've recently returned to the task, this time with some assistance.

Fellow Amateur Telescope Makers of Boston (ATMoB) members John Reed and Phil Rounseville inspired me to get going again, and I hope to have my homebuilt 6-inch Dob in operation by year's end. The lesson I've learned: Unless you're a do-it-yourself whiz, don't tackle mirror-grinding without the guidance of an experienced telescope-maker.

If pushing glass isn't your cup of tea or you lack the necessary time, you can purchase completed optics and then assemble your own scope. *Build Your Own Telescope*, written by former *Astronomy* editor Richard Berry, and *Making & Enjoying Telescopes*, by Robert Miller and Kenneth Wilson, showcase several nice designs that can be made with a minimal amount of materials and effort. An older, but still useful, telescope-making guide is Sam Brown's *All About Telescopes*, available from Edmund Scientific.

Want to learn more about telescope-making? Go to the official Stellafane web site at www.stellafane.com. In addition to telescope-making tips and a list of resources, you'll find information about the Stellafane Convention. If you live in the northeast United States or southeast Canada, why not join me at this year's Stellafane? It runs July 28–30. Just don't tease me about my teddy bear!

Next month: We'll take a telescopic tour of Hercules. Be sure to read Phil Harrington's binocular close-up of this constellation ("It's Superman!" page 16) this month. Clear skies!

EIGHTY YEARS AGO, astronomy enthusiasts gathered at Stellafane to swap telescope-making ideas and show off their inventions. ARCHIVES, SPRINGFIELD TELESCOPE MAKERS

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BY PHIL HARRINGTON

It's Superman!

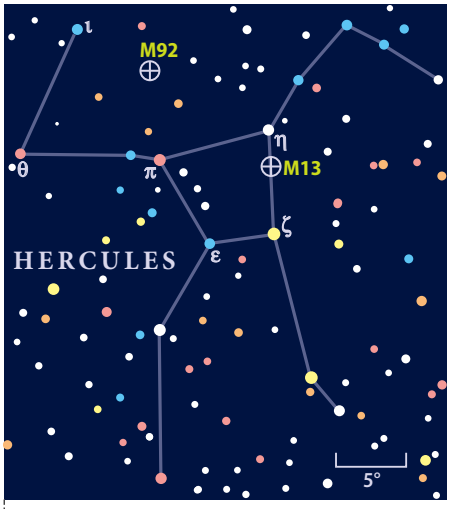
Okay, that might be a stretch. You're not likely to see someone flying around the sky wearing a leotard and red cape anytime soon. But a superman hovers among the stars tonight. Hercules, that mythical do-gooder, proudly marches across the sky every summer evening. According to legend, Hercules is the Roman incarnation of Heracles, the son of Zeus, king of the gods. Hercules' strength and bravery became legend during his "12 Labors," in which he battled lions, man-eating birds, and the nine-headed Hydra, among others.

Given his prominence in ancient legends, you'd think Hercules' celestial presence would be more obvious. While the sky's other superhero, Orion, beams in the winter sky, you'll have to look hard to see Hercules. To find him, go about a third of the way from the bright star Vega in Lyra to Arcturus in Boötes. Celestial artists often draw Hercules as kneeling and upside down among the stars, a pose that goes back to the constellation's Greek origins. Although the Greeks imagined a kneeling figure here, they didn't identify it by name. Greek poet Aratus (third century B.C.) called the constellation "the Phantom whose name none can tell."

Four of Hercules' brightest stars fall into a keystone pattern that contains this month's first binocular target. The great Hercules globular cluster **M13** (NGC 6205) resides along the western side of the keystone, about a quarter of the way between the stars Eta (η) and Zeta (ζ) Herculis. Aim there, and you should see a faint blur of light centered between two faint "sentry stars" standing at attention to either side. Through binoculars, M13 looks like a fluffy cotton ball suspended against the sky. You'll need a telescope to see any of its estimated 100,000 individual stars.

Can you imagine what a spectacular sight those stars must be from a planet orbiting one of them? Isaac Asimov's famous science-fiction story *Nightfall* tells of a civilization on the planet Lagash, which orbits a six-star system. Lagash's complex orbit was such that at least one of those six stars always lit the planet's sky. No one alive had witnessed night's darkness. But once every 2,049 years, five of the stars would be visible only from one side of the planet, while an eclipse would cover the sixth star on the other side. On that occasion, the sky would be completely dark.

Learning that an eclipse was imminent and not knowing what darkness is, the people of Lagash were stricken with fear and madness over the pending terror. But just as the eclipse occurred, and the planet's lone remaining sun was extinguished, the entire sky suddenly burst with uncountable distant stars. It turned out that Lagash lies within a globular cluster.



YOUR QUEST for this month's targets may not be quite as daunting as Hercules' 12 Labors, but it's still an adventure. This finder chart will help you. *ASTRONOMY:* ROEN KELLY

Hercules holds in store a second globular, **M92** (NGC 6341), for our binoculars. To spot it, aim along the northern side of the Hercules keystone, marked by the stars Eta and Pi (π) Herculis. Both ought to fit in the field of view. Look for a tight pair of fainter stars to their north; Eta, Pi, and this pair combine to form a fairly conspicuous right triangle. From that fainter pair, which collectively marks the triangle's right angle, head north-northeast about half a field (3°) to M92. Like M13, M92 will look like a misty glow accented with a brighter central core. Both globulars may squeeze into the same field of wide-angle binoculars.

Let's try to find a fun asterism that isn't plotted on any star chart I know about. A couple of months ago, I bumped into it while doing some early morning observing for this column. I jokingly call it the SS *Hercules*, because it reminds me of a sailboat. To find it, head about a binocular field (5°) northeast of M92, to the star Iota (ι) Herculis, and then another half a field (3°) due east. There, you should see a group of seven stars. To me, the two brightest form the mast, three fainter stars outline the deck, and two others mark the underside of the hull. Drop me a line at phil@philharrington.net and let me know if you spot the good ship SS *Hercules*.

Plenty of other treats lie in the constellation Hercules to entertain us this month. Come over to Astronomy.com, where I spell a few of them out. And next month, we'll cruise the Milky Way toward the galactic center, where, once again, we will prove two eyes are better than one! A

ONLINE EXTRA More binocular-friendly targets adorn Hercules. To find them, visit www.astronomy.com/toc.

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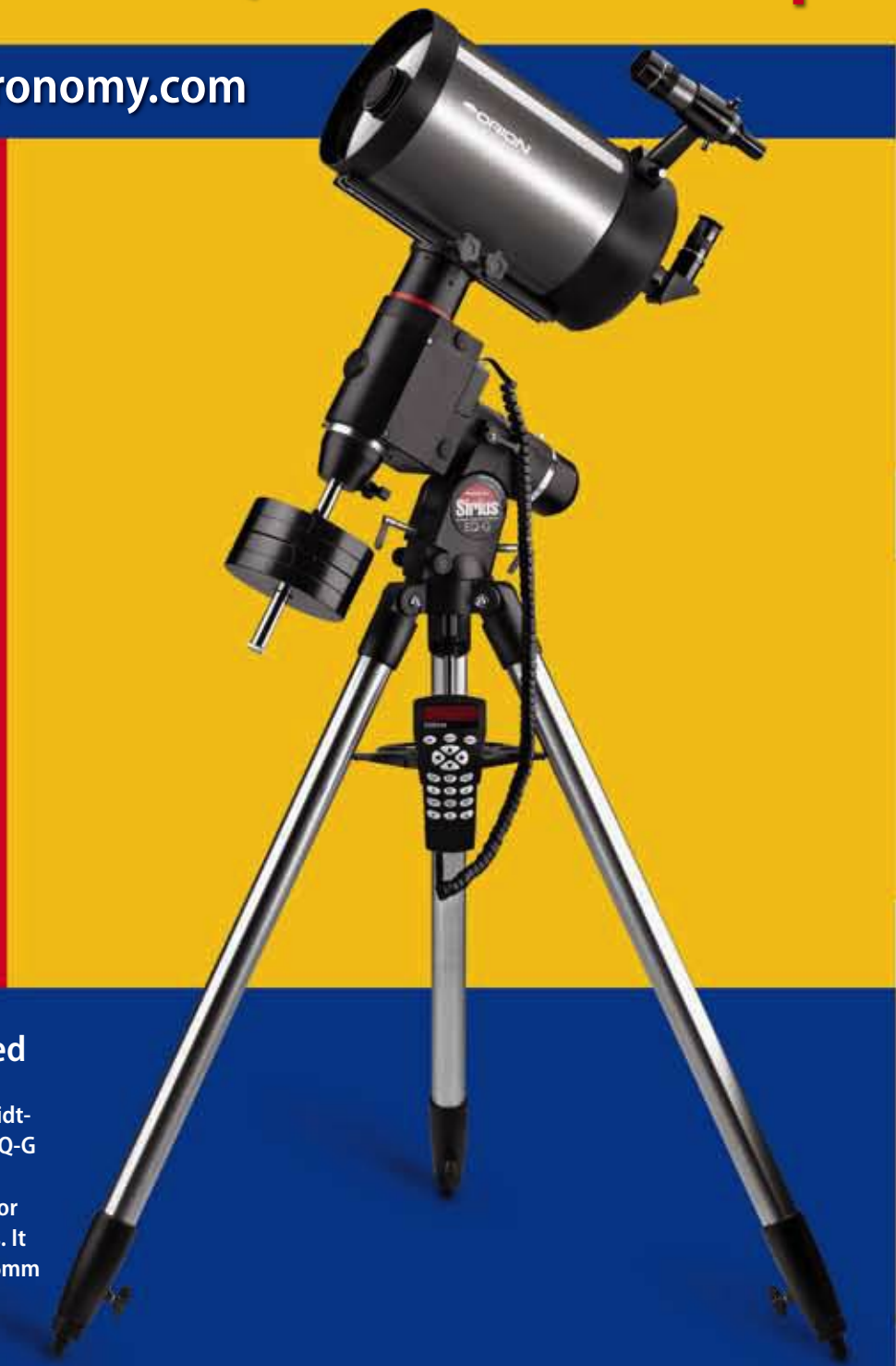

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No Purchase Necessary. The official start date for the *Astronomy* Summer 2006 Sweepstakes is March 30, 2006. Official entry forms are bound in the June 2006, July 2006, and August 2006 issues of *Astronomy*. The *Astronomy* Summer 2006 Sweepstakes is open to residents of the United States and Canada (except Quebec) only, 18 years of age or older. Employees (and their dependents and immediate household members) of Kalmbach Publishing Co., their advertising and promotional agencies, and participating sponsors are not eligible to participate.

Sweepstakes Entry. To enter, complete and mail the official entry form or a postcard with name, address, city, state or province, zip and telephone number on a postcard and send it to: *Astronomy* Summer 2006 Sweepstakes, P.O. Box 378, Waukesha, WI 53187-0378. Or enter online at www.astronomy.com by filling in the Online Entry form and hitting the SEND key. The Online Entry form must be filled out completely to be eligible. Incomplete or defaced entry forms are void. One entry per household. The official ending date for the *Astronomy* Summer 2006 Sweepstakes is July 14, 2006, and all entries must be transmitted or postmarked no later than that date.

Prizes and Odds of Winning. One drawing will be held on or about September 12, 2006, for the following awards: One Grand Prize consisting of an Orion Sirius 8 EQ-G GoTo Schmidt-Cassegrain (retail value $1,899.95). Two First Prizes consisting of an Orion SkyQuest™ XT8 IntelliScope® and hand controller (retail value $599.95). Three Second Prizes consisting of an Orion StarShoot™ Deep Space CCD Color Imaging Camera (retail value $399.95). Four Third Prizes consisting of an Orion SkyLine™ Green Laser Pointer (retail value $99.95). Cash equivalents of merchandise will not be awarded. Substituting prizes is not allowed. Any applicable federal, state and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation for *Astronomy* magazine is 130,601. Sweepstakes void in Quebec and void where prohibited.

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Shutterbug Tests March 23 and 25 show the HiRISE camera on NASA's Mars Reconnaissance Orbiter is working fine. NASA expects 10,000 images from HiRISE during the next 3 years.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

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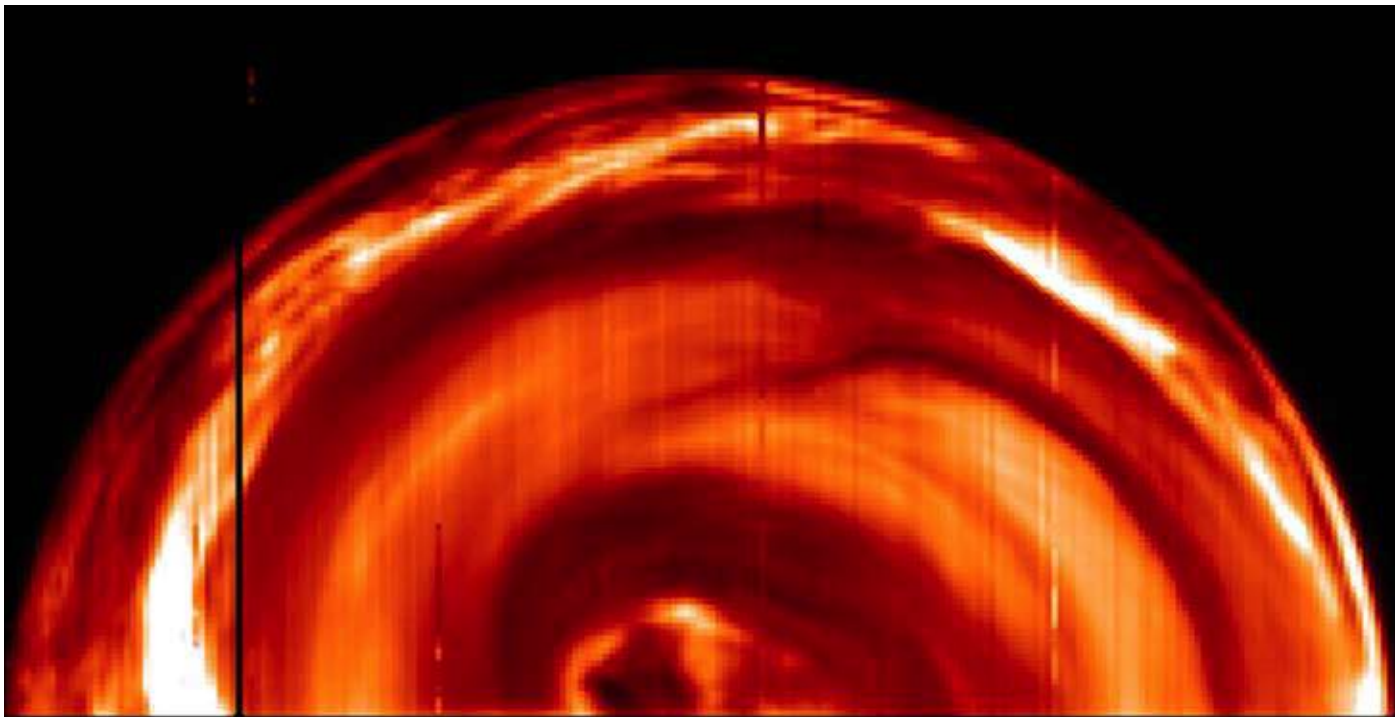
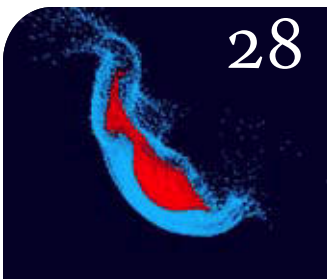


ESA

HOT ZONE. Venus Express captured this false-color infrared view of Venus' night side on the probe's first orbit. In this image from the Visual and Infrared Thermal Imaging Spectrometer (VIRTIS), the brightest areas are clouds about 34 miles (55 kilometers) above the planet's surface. This first-ever view of Venus' south pole (bottom center) reveals a structure atmospheric scientists call a polar vortex. Venus Express was about 128,300 miles (206,450 km) from the planet when VIRTIS took this image.



22 New dark galaxy found

24 Space station may get its own satellite

25 Falling galaxies trail gas

28 "Xena" downsized

28 Venus Express arrives

On April 11, the European Space Agency's (ESA) Venus Express probe became the first spacecraft to orbit Venus since 1994. Even as the spacecraft arced through its first ellipse, eager scientists put the probe's instrumental muscles to work.

On April 12, the Visual and Infrared Thermal Imaging Spectrometer (VIRTIS) captured the planet's night side through a 1.7-micrometer infrared filter. The photo reveals spiral cloud structures in the lower atmosphere, about 34 miles (55 kilometers) above the surface.

"We expect to see these spiral structures evolve very quickly," says Venus Express project scientist Håkan Svedhem. Brighter regions correspond to areas with thinner cloud cover, which allows thermal radiation to be imaged at lower altitudes.

The VIRTIS image reveals a dark swirl of thick clouds almost directly over Venus' south pole. Scientists know a similar structure swirls over the planet's north pole. Now, Venus Express confirms the presence of a polar vortex at the south pole as well.

The first Venus Express images are of relatively low resolution because the spacecraft's initial orbit takes it far from the planet. Mission controllers reduced the orbit's size through April and May, which will bring about a hundredfold resolution improvement. — **FRANCIS REDDY**

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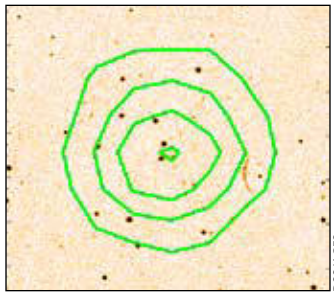
New dark galaxy found

First results from the Arecibo Galaxy Environment Survey (AGES) suggest the discovery of a new dark galaxy — an enormous mass of dust and gas that apparently has yet to form stars. The radio source lies near NGC 1156, a seemingly isolated irregular galaxy found in Aries. The dark galaxy appears to be about 200,000 light-years across and lies approximately 153 million light-years from Earth.

"The new source … contains huge amounts of hydrogen gas, but it was missed in all previous searches as it doesn't appear to contain many bright stars," says Cardiff University's Robbie Auld. He estimates the cloud contains about 580 million solar masses.

Astronomers began the first stage of AGES, the most sensitive such survey to date, in December 2005. They scan the sky for the 21-centimeter radio-fingerprint of neutral hydrogen, looking for hidden galaxies.



DSS/AGES

DARK VISION. Radio contours (green) show massive amounts of neutral hydrogen, but no stars.

Last year, similar techniques led to the discovery of VIRGOHI21, the first dark galaxy recognized. "We now need to follow up observations at other wavelengths and work out exactly how many stars this new galaxy may or may not contain," Auld says. He presented his results at the Royal Astronomical Society's meeting April 6. — **F. R.**

COROT set to join planet search

Astronomers anticipate finding between 10 and 40 earthlike planets with COROT, the COnvection, ROtation, and planetary Transits spacecraft slated for launch in June 2006. Led by CNES, the French national space agency, the project will study vibrations on nearby stars and search for rocky planets outside the solar system.

COROT will search for earthlike planets around more than half a million stars. To date, the search for planets around stars outside our solar system has revealed roughly 160 planets orbiting Sun-like stars. Most extrasolar planets detected with ground-based telescopes are Jupiter-size or larger.

CNES/ACTIVE DESIGN

GOOD VIBRATIONS. COROT will study stellar pulsations and search for planets.

COROT may represent the best opportunity to advance the search for earthlike planets in the near future. In February, NASA's fiscal year 2007 budget proposal included the cancellation of Terrestrial Planet Finder — a mission to study extrasolar planets and whether they might be suitable for life to evolve — and delayed launch of SIM PlanetQuest, another planet-hunter, until 2014. Darwin, a planet-searching space mission the European Space Agency is now assessing, won't launch before 2015. — **LAURA LAYTON**

CG4's last stand

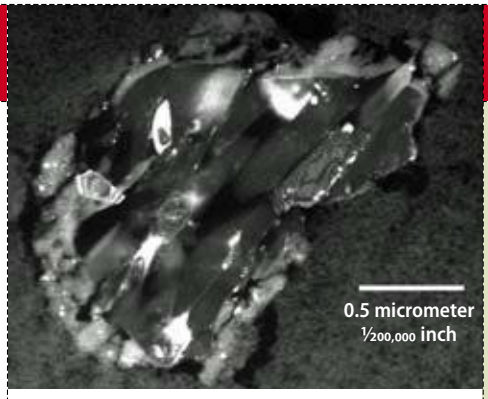
Astronomers catalog CG4, a comet-shape smattering of gas and dust about 1,300 light-years away in the constellation Puppis, as a cometary globule. Such nebulae are small, isolated star-forming regions within the Milky Way. The CG4 nebula contains enough matter to form several Sun-like stars.

The nebula's head is about 1.5 light-years across, and its tail spans some 8 light-years. Nearby stars illuminate the nebula, but, at the same time, their energy is sweeping away its tiny light-scattering particles. Electrically charged hydrogen from nearby stars suffuses CG4 with a red glow.

Travis Rector of the National Optical Astronomy Observatory (NOAO) and Tim Abbott of the Cerro Tololo Inter-American Observatory (CTIO) imaged CG4 using CTIO's 157-inch (4 meter) Blanco Telescope. The image is the 1,000th added to NOAO's online image gallery, www.noao.edu/image_gallery. — **L. L.**

T. A. RECTOR AND T. ABBOTT/NOAO/AURA/NSF/UNIVERSITY OF ALASKA ANCHORAGE

EVAPORATING CLOUD. Star formation in cometary globule CG4 is depleting dust and gas in its 1.5 light-year-diameter head (left), which nearby stars illuminate.



MYSTERY MINERAL. **Olivine in Comet Wild 2's dust must have formed in the hot inner solar system.** NASA/JPL/CALTECH

Hot origins for Comet Wild 2

Scientists studying comet dust samples NASA's Stardust mission returned in January are trying to understand how particles that clearly formed close to the Sun found their way into a comet. The finding suggests the young Sun ejected matter that traveled to the outer solar system.

Scientists believe comets formed at the solar system's frigid fringes, where their ices are stable. Yet, Stardust samples contain crystals of olivine, a mineral compound made mostly of magnesium and iron that forms in relatively high temperatures. "It's certain such materials never formed inside this icy, cold body," says the University of Washington's Donald Brownlee, Stardust's principal investigator.

"It seems that comets are not composed entirely of volatile-rich materials, but rather are a mixture of materials formed at all temperature ranges, at places very near the early Sun and at places very remote from it," says Michael Zolensky, Stardust curator at NASA's Johnson Space Center in Houston.

Many stars embedded in protoplanetary disks expel matter in twin jets called bipolar outflows. The scientists suggest similar jets from the early Sun may have transferred heat-processed material to the solar system's cold outer reaches, where it became incorporated into comets. Brownlee and colleagues presented their findings March 13 at the annual Lunar and Planetary Science Conference held in League City, Texas. — **L. L.**

Secret rivers

Using radar data from space, British scientists have found that lakes beneath Antarctica's ice cap can spill over and create temporary rivers.

NASA/ESA/THE HUBBLE HERITAGE TEAM (STScI/AURA)/A. RIESS (STScI)

WHEEL OF SUPERNOVAE. **Hubble imaged spiral galaxy NGC 1309 in 2005. Studies of the galaxy's exploding stars are helping refine the cosmic distance scale.**

Pinwheel with a purpose

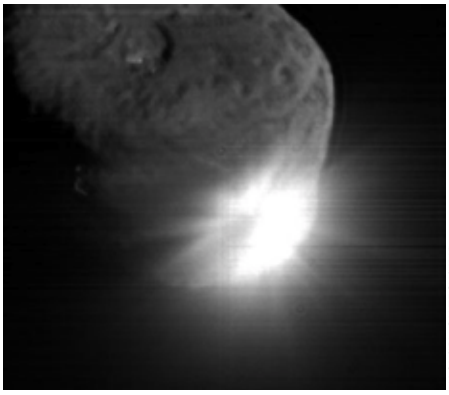
Spiral galaxy NGC 1309 is helping astronomers measure how fast the universe is expanding. NGC 1309 was home to a type Ia supernova designated SN 2002fk, whose light first reached Earth September 2002. Astronomers use supernovae like SN 2002fk to calibrate their yardstick for the rest of the universe.

By comparing the brightnesses of nearby type Ia supernovae to more distant ones, scientists can better understand the universe's expansion. But the method works only if astronomers know the distances to the supernovae's host galaxies.

That's where NGC 1309 and the Hubble Space Telescope come in. Hubble's high resolution lets astronomers see the galaxy's Cepheid variable stars. These stars' varying apparent brightnesses tie directly to their true luminosities. The stars are intergalactic mile markers signaling to astronomers the true distances. There's a catch: Dimming from dust in our galaxy can throw off the readings.

Astronomers think they've taken this effect into account for NGC 1309. The galaxy's Cepheids tell them it lies 100 million light-years away.

Hubble imaged NGC 1309 in August and September 2005. The spiral is one of about 200 galaxies that make up the Eridanus group. — **LIZ KRUESI**



NASA/JPL-CALTECH/UMD

GUSHER. **NASA's July 4, 2005, impact on Comet Tempel 1 yielded enough water to fill 260 Olympic-size swimming pools.**

Deep Impact shed lots of water

After NASA's Deep Impact probe slammed into Comet 9P/Tempel 1 in July 2005, a team of U.K. and U.S. scientists monitored X rays from the comet using NASA's Swift satellite. "The Swift observations reveal that far more [frozen] water was liberated and over a longer period than previously claimed," says team leader Dick Willingale.

The comet grew ever brighter in X rays following the impact, and the outburst lasted 12 days. Water molecules generate X rays as they interact with the solar wind, a fast-moving stream of particles from the Sun. In all, Tempel 1 shed some 275,000 tons (250,000 metric tons) of water during the outburst — enough to fill more than 260 Olympic-size swimming pools. Willingale reported the result April 4 at the Royal Astronomical Society's meeting at the University of Leicester in England.

Until NASA's Deep Impact mission closed on Comet Tempel, cometary water had never been directly observed. "We have known for a long time that water ice exists in comets, but this is the first evidence of water ice on comets," says Jessica Sunshine, lead author of a *Science* report published online February 2. Ice covers about 1 percent of the comet's 45-square-mile (117 square kilometers) surface area, and only about 18,000 square feet (1,672 square meters) of this is pure water ice. — **L. L.**

Space station may get its own satellite

Amateur astronomers observe the International Space Station (ISS) as an easily visible star parading through the dawn and dusk skies. Televised views of ISS come from docking Soyuz and shuttle vehicles or from "helmet cams" attached to the spacesuits of astronauts working outside the station.

But if recent successful tests of a unique piece of space hardware convince NASA to build and fly an operational unit, there'll be a new twist to watching ISS. In fact, this new device may help spacewalkers work more effectively and, in some cases, may eliminate the need for astronauts to perform some exterior work.

NASA calls the new hardware the Miniature Autonomous Extravehicular Robotic Camera, or Mini AERCam for short. It's designed to serve as a free-flying robotic inspection vehicle. The craft measures 7.5 inches (19 centimeters) across and weighs about 10 pounds (4.5 kilograms). It moves around using blasts from xenon-gas thrusters. It can be equipped with cameras pointing in different directions and chemical sniffers to detect exterior leaks. Mini AERCam's outer skin is cushioned to handle any unintended collisions with ISS.

The satellite could carry tools to a spacewalker at a distant location on the station or, someday, take plug-in units to work sites and install them itself. Future designs may be able to manipulate switches, dispense tape to secure insulation blankets or loose wires, or fire gas blasts to dislodge debris.

If built for use on the current space station, Mini AERCam's descendant would be a free-flyer based outside ISS. It would reside in a "home base" that would enable the robot to refuel and recharge itself. When it requires a human to repair it, the craft could fly itself into an airlock.

Some NASA engineers dream about an operational capability that would support both teleoperation, in which astronauts inside the station control robots on the outside, and full autonomy. In this latter mode, the free-flyer would move from its home base to any region of interest, steer itself to avoid obstacles, and then hold the proper position to carry out its assigned task.

NASA

SATELLITE'S SATELLITE. **Mini AERCam carries twin cameras, a headlight built from a light-emitting-diode array, and xenon-gas thrusters. Its successor may one day be able to perform tasks that would otherwise require spacewalks.**

NASA

FACE TO FACE. **Design Lead Nathan Howard monitors a Mini AERCam test at NASA's Johnson Space Center.**

The unit tested last year on air-bearing tables (which let the craft glide on a nearly frictionless layer of air) was a direct descendant of the Sprint AERCam that flew in open space during a shuttle mission in December 1997. Astronaut Winston Scott deployed and retrieved the free-flying robot early December 3, 1997, during STS-87's second spacewalk. For about 75 minutes, the robot conducted a series of maneuvers and observations designed to evaluate the utility of mobile robotic cameras. It flew in the space shuttle's payload bay and rose up to 40 feet (12 meters) above it.

On future missions, when vastly improved free-flying robotcams keep an eye on space vehicles and astronauts, these devices will be the ultimate "satellite watchers." — **JAMES OBERG**

LUCA CORTESE

SLAM DUNK. **Gaseous filaments (purple) form as the Blue Infalling Group dives into galaxy cluster Abell 1367.**

Falling galaxies trail gas

Galaxies falling into the Abell 1367 galaxy cluster trail enormous filaments of gas, says Luca Cortese at Cardiff University in Wales. Cortese led an international team studying the physical properties of the Blue Infalling Group (BIG), a galaxy swarm that's plunging into Abell 1367's heart at 3.8 million mph (6.1 million km/h).

The team detected gas threads spanning 490,000 light-years. No one can yet explain how these structures formed. "This is the first time we have found an example of a galaxy group midway through its transformation that is close enough for us to have a really good look at the structures surrounding the galaxies," Cortese explains.

Discovered in 2002, BIG has the highest density of star-forming objects ever seen in local clusters. It contains two giant galaxies, at least 10 dwarf galaxies or extragalactic clouds, and more than a billion solar masses of gas. BIG lies 300 million light-years away.

Cortese presented the findings April 5 at the Royal Astronomical Society's meeting. The study will appear in an upcoming issue of *Astronomy and Astrophysics*. — **F. R.**

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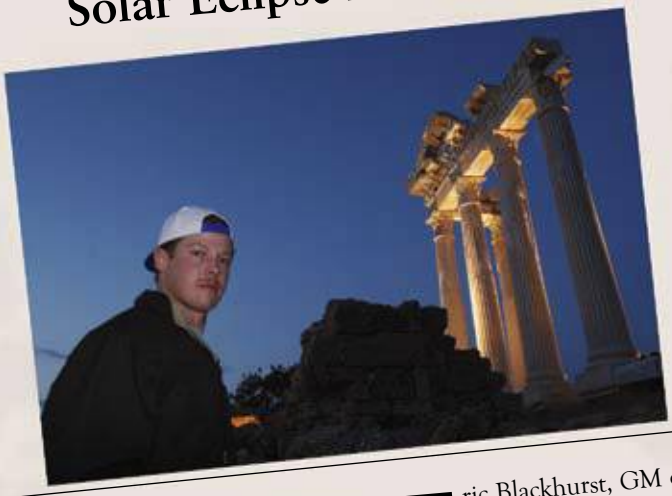

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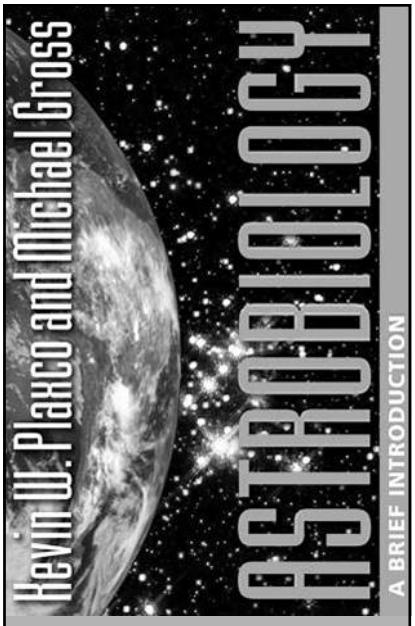

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NASA/JPL/SSI

GREAT RED SPOT AND COMPANY. A new mosaic shows off the whorls and festoons of Jupiter's clouds.

Cassini team releases best Jupiter map ever

New global mosaics of Jupiter released March 27 by the Cassini imaging team are the most detailed color maps of the giant planet ever produced. The images show features as small as 75 miles (120 kilometers) across.

On December 11 and 12, 2000, as Cassini passed Jupiter en route to Saturn, the spacecraft's narrow-angle camera snapped 36 images covering Jupiter's northern and southern hemispheres. Cassini acquired near-infrared and blue-filtered images every hour as the planet rotated beneath the spacecraft.

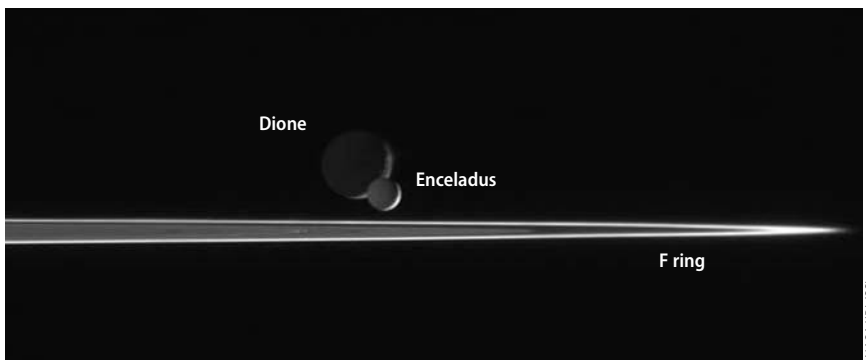
The imaging team transformed the two-color image sets into full-color maps of the solar system's largest world. — **F. R.**

Galaxies spew crushed glass

Rare colliding spiral galaxies harbor glasslike silicate crystals at their violent cores. NASA's Spitzer Space Telescope's infrared spectrograph spied clouds of the particles in 21 of 77 bright and dust-filled merging galaxies studied. Astronomers call these systems ultraluminous infrared galaxies, or "ulirgs."

"It's as though there's a huge dust storm taking place at the center of merging galaxies," says Lee Armus of the California Institute of Technology in Pasadena. As ulirgs merge, silicate grains like those making up Earth's sandy beaches are swept up, heated, and transformed into crystals. "The silicates get kicked up and wrap the galaxies' nuclei in giant, dusty glass blankets."

Although the crystals are easily destroyed, researchers think they're being churned out by massive stars faster than they disappear. The study appears in the February 20 *Astrophysical Journal*. — **L. L.**



NASA/JPL/SSI

Moons over F ring

The Cassini spacecraft's narrow-angle camera imaged a pair of crescent moons above Saturn's F ring March 3. Cassini captured 314-mile-wide (505 kilometers) Enceladus as it began passing in front of 700-mile-wide (1,126 km) Dione. "Saturn shine" illuminates those parts of the moons' disks not lit by the Sun. — **F. R.**

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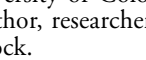

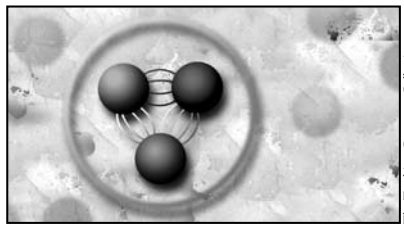

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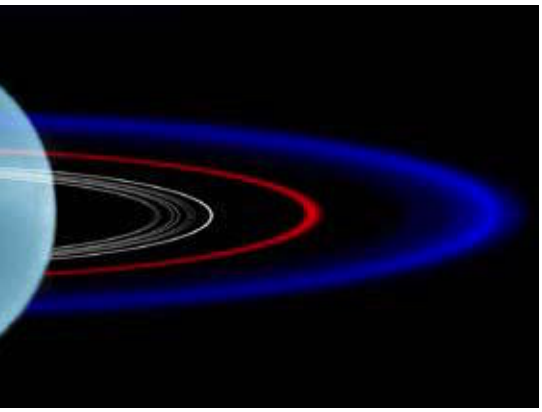


IMKE DE PATER

COMMON THREAD. Most rings are red, but the outer ring of both Uranus and Saturn is blue — and each appears to harbor an embedded icy moon.

Icy moons make blue rings

Uranus' outermost ring, discovered last year, is decidedly blue, a trait it has in common with Saturn's diffuse E ring. "The blue color says that this ring is predominantly submicron-size material, much smaller than the material in most other rings, which appear red," says Imke de Pater, lead author of a study on the ring published April 7 in *Science*.

The team suggests it's no coincidence the solar system's only blue rings are associated with the small moons Enceladus and Mab. "The outer ring of Saturn is blue and has Enceladus right smack at its brightest spot, and Uranus is strikingly similar, with its blue ring right on top of Mab's orbit," de Pater explains.

Mab, only 15 miles (24 kilometers) across, is 1/20 of Enceladus' size and too small to support that moon's level of geological activity. Neither Mab nor its ring show up at near-infrared wavelengths. The astronomers think Mab is probably covered with water ice, like Uranus' other outer moons, and impacts create the debris forming the rings.

The scientists expect both of the solar system's blue rings owe their tint to subtle forces that allow smaller particles to survive while larger ones are recaptured by the moon. — **F. R.**

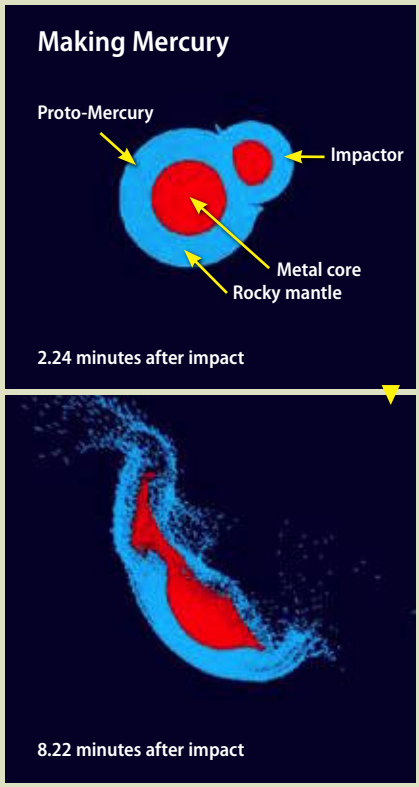
Mercury blast splashed Earth

New computer simulations of a giant impact on the young planet Mercury shed light on the planet's odd makeup. Moreover, some of the debris thrown out by the impact could have made its way to Earth and Venus.

"Mercury is an unusually dense planet, which suggests that it contains far more metal than would be expected for a planet of its size," says Jonathan Horner of the University of Bern, Switzerland. Planetary scientists think Mercury is what's left of a larger parent body that was involved in a catastrophic collision, but, he explains, "Until these simulations, we were not sure why so little of the planet's outer layers was reaccreted following the impact."

Horner and colleague Augustin Anic simulated collisions between a proto-Mercury 2.25 times the planet's current mass and an impactor half of Mercury's present mass. The result is a dense, metal-rich body and a swath of escaping debris.

The scientists then fed the debris trajectories into a second set of simulations. The team tracked the particles until they either landed on a planet, fell into the Sun, or traveled beyond Jupiter. Half of the ejected material took as long as 4 million years to fall back to Mercury. During such time, nongravitational forces could alter particle orbits so much they'd never meet Mercury again.



JONATHAN HORNER

JONATHAN HORNER

COLLISION ALERT. In a new simulation, a giant object smashes into Mercury (top) shortly after the planet forms. Minutes later (bottom), rocky debris begins a journey that may take it to Earth.

Some of the debris reached Venus and Earth. In fact, Horner thinks Earth may contain as much as 17 million billion tons (16 million billion metric tons) of proto-Mercury material. He presented the study at the Royal Astronomical Society's meeting April 5. — **F. R.**

BRIEFCASE

Oceans connected

A study of fossil fish teeth in the April 21 *Science* shows the Atlantic and Pacific Oceans first hooked up 41 million years ago. — **F. R.**

Earthly gammas

Scientists suspected Terrestrial Gamma-ray Flashes, first found in the 1990s, were caused by lightning. Now, a March 17 *Geophysical Research Letters* study proves they originate in cloud-to-cloud bolts. — **F. R.**

"Xena" downsized

The "tenth planet" discovered last year isn't as big as once thought. In February, a team led by discoverer Michael Brown of Caltech turned the Hubble Space Telescope toward 2003 UB_{313} — known by its unofficial nickname, Xena. To everyone's surprise, the object is just 1,490 miles (2,397 kilometers) across, or about 5-percent larger than Pluto.

The smaller size means Xena is one of the solar system's shiniest bodies — only Saturn's moon Enceladus beats it. Could Enceladus-like geysers be keeping Xena bright?

Not likely, says Brown. He thinks that when Xena is closest to the Sun, surface ices sublimate to make a thin atmosphere. When Xena moves farther away, the gases refreeze and coat the surface with frost. — **F. R.**

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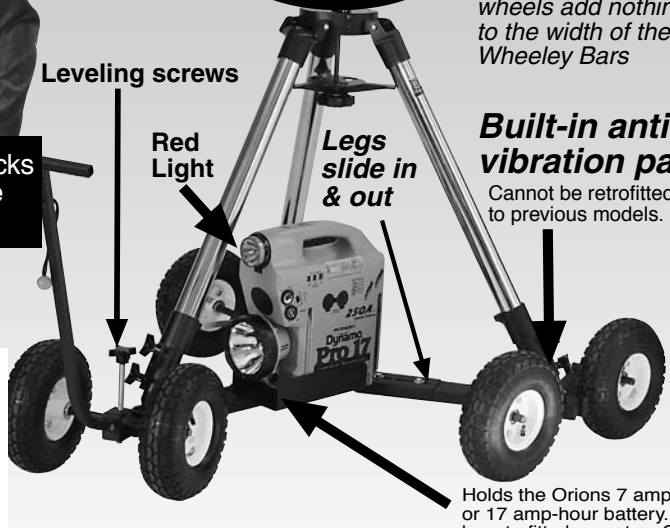

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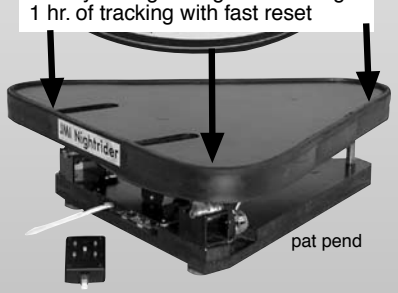

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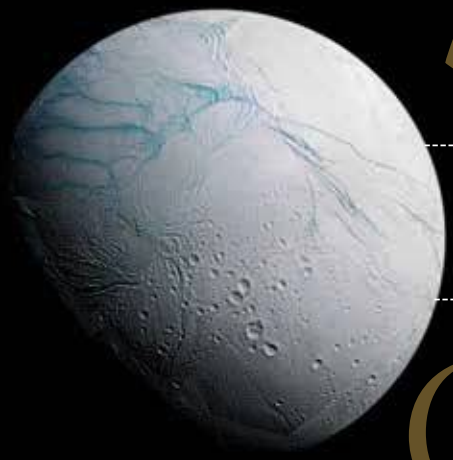
Cassini Unveils Saturn



Nearly 2 years into its extraordinary mission, NASA's Cassini spacecraft reveals the ringed planet's secrets. /// BY ALFRED S. McEWEN

CASSINI, NOW nearly halfway through its primary mission, has made some astonishing finds. They include geyser-like eruptions on the moon Enceladus, newfound structures in Saturn's rings, Hyperion's sponge-like appearance, and, on Titan, evidence of an ice volcano and a hydrocarbon lake. UNLESS OTHERWISE CREDITED, ALL IMAGES NASA/JPL/SSI

MOONS, clockwise from above: Enceladus, Hyperion, Phoebe, and Titan.

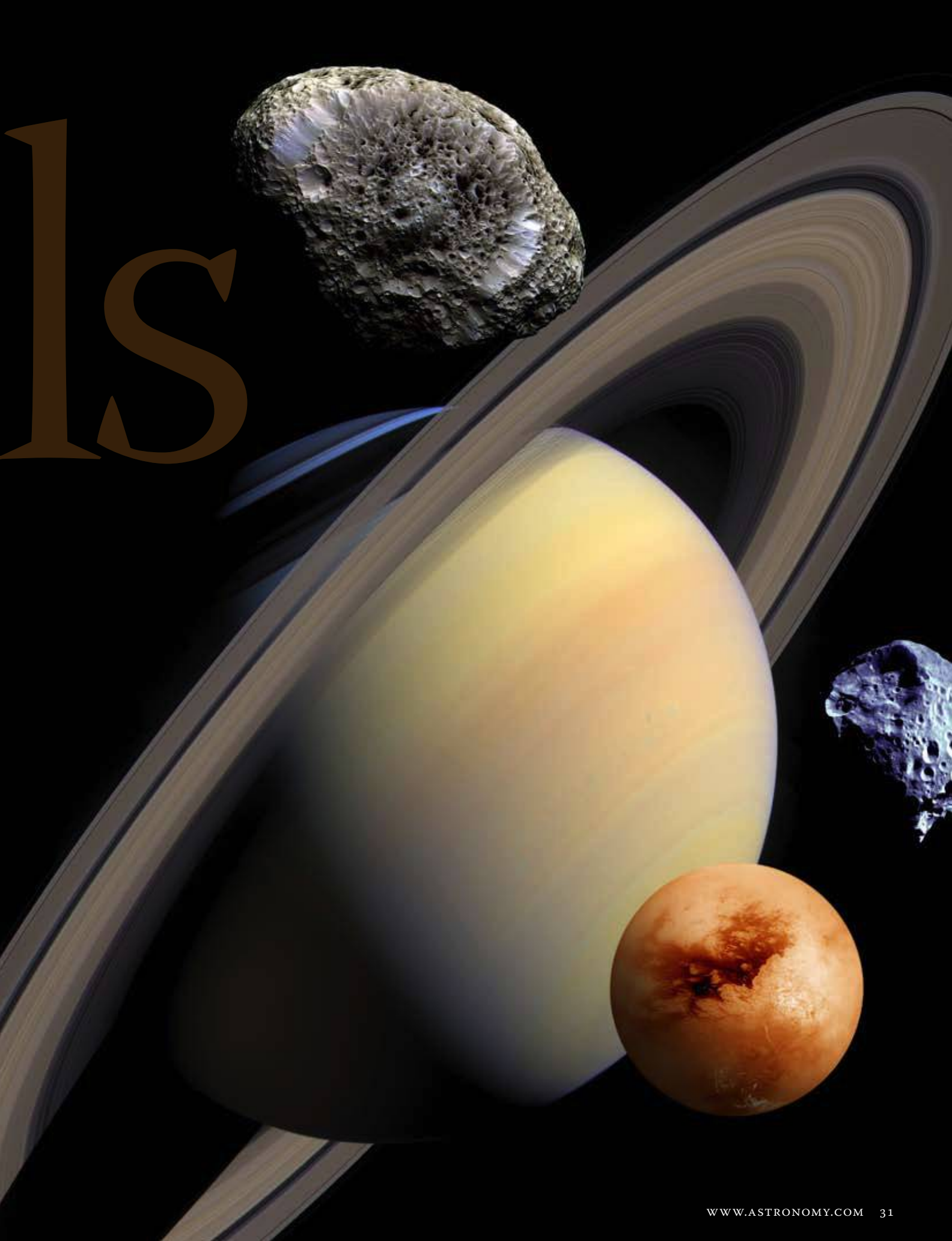
On the night of June 30, 2004, the Cassini spacecraft fired its main engine and became a new satellite of Saturn. Engineers and scientists who had worked for decades on this joint NASA-European mission erupted into cheers at the Jet Propulsion Laboratory (JPL) in Pasadena, California. The European Space Agency's Huygens probe rode piggyback on Cassini until it separated in December 2004 to prepare for its historic landing on Saturn's largest moon, Titan. The two craft had traveled together for more than 1.9 billion miles (3 billion kilometers) since their 1997 launch.

Now, as Cassini's 4-year primary mission nears its halfway point, scientists have collected images and other data beyond their greatest expectations. Cassini has shown us one icy moon, Enceladus, where geysers of water blast into space, and another, Titan, with sinuous channels that liquid methane may have carved. Saturn storms crackle with lightning bolts 1,000-fold more powerful than any observed on Earth. And Cassini's views of structure in the planet's signature rings astonished scientists.

Cassini crossed the plane of Saturn's rings both before and after its orbit-insertion burn, a situation that offered scientists extraordinary views. Imaging team leader Carolyn Porco of the Space Science Institute in Boulder, Colorado, said, "We are seeing structure, literally, that we've never imaged before." She interpreted the images as they appeared live on NASA TV. "The beauty and clarity of these images … are shocking to me."

Charles Elachi, director of the Jet Propulsion Laboratory and leader of Cassini's radar experiment team, echoed her view. "For years, we've dreamed about getting pictures like [these]. After all the planning,

Alfred S. McEwen *is a member of the Cassini mission imaging team at the University of Arizona, Tucson. He's also principal investigator for the high-resolution imager aboard Mars Reconnaissance Orbiter.*



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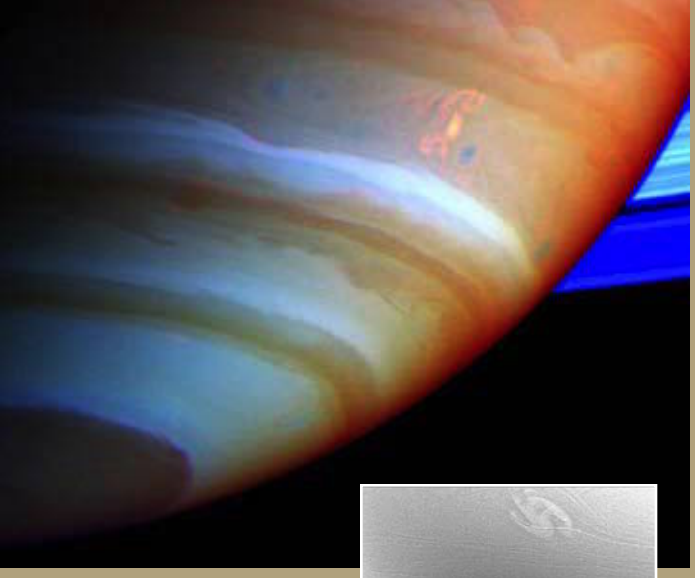
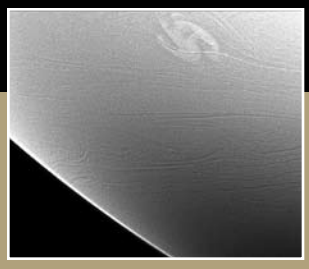
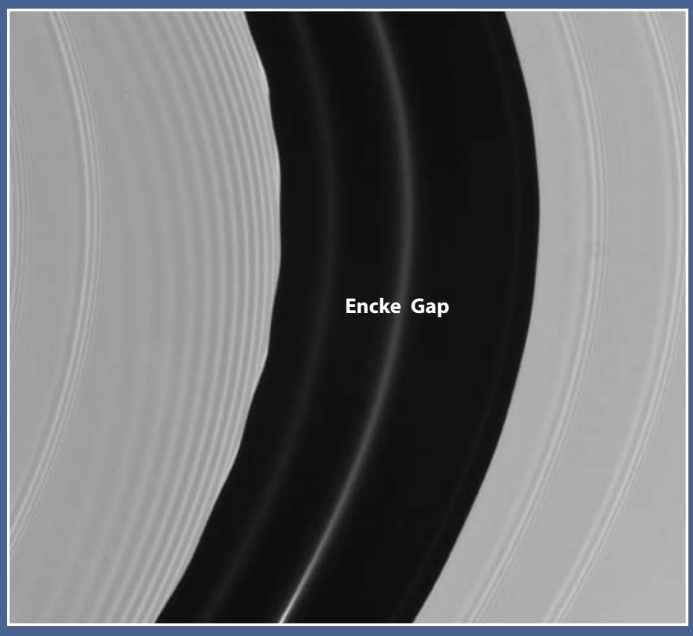




Stormy skies

▲ THIS BRIGHT SWIRL of convective clouds appeared in Saturn's southern hemisphere in mid-September 2004. This false-color image, which comprises near-infrared observations, shows areas with more methane in redder colors. *Inset*: Cassini imaged the January 2006 storm only by "ringshine," which is 10 times brighter than a Full Moon on Earth.



waiting, and worrying, just seeing these first images makes it all worthwhile."

Saturn's realm

Saturn is the sixth planet from the Sun and orbits at an average distance of 9.6 astronomical units (AU), where 1 AU is the average distance between Earth and the Sun. Saturn completes one circuit around the Sun every 29.5 Earth years. Saturn, like Jupiter, is a gas giant. It's made from about 96-percent hydrogen and 4-percent helium and rotates once every 10 hours and 39 minutes.

The saturnian system is wonderfully complex, with 34 named moons — only 18 of which were known when Cassini launched — and an extended family of rings. From the planet outward, scientists designate the most prominent rings with the letters D, C, B, and A; only the latter three can be seen in modest telescopes from Earth. Beyond the bright A ring lie the faint, braided F ring — discovered by Pioneer 11 in 1979 during the first phase of Saturn exploration — a faint G ring farther out, and, finally, a broad, diffuse E ring.

A menagerie of small moons, including several new moons Cassini discovered, orbits within the rings. Gravitational interactions between the small moons and ring particles sculpt both the broad and narrow gaps between rings.

Five medium-size icy satellites, ranging in diameter from 247 to 949 miles (398 to 1,530 kilometers), orbit embedded in the tenuous E ring: Mimas, Enceladus, Tethys, Dione, and Rhea, in order of their distance from the planet. Much farther away, about 20.3 times Saturn's radius, orbits the haze-shrouded, planet-size moon Titan, which is actually larger than the planet Mercury. Beyond Titan lies another zoo of irregularly shaped moons, including tumbling Hyperion, two-toned Iapetus, and ancient Phoebe.

Unlike Jupiter, Saturn's spin axis tilts steeply (27°) to its orbital plane. This means Saturn and the regular moons, which orbit in the planet's equatorial plane, have definite seasons. It's currently late summer in Saturn's southern hemisphere, which means constant sunlight hits the south poles of Saturn and the regular moons. This situation begins to reverse after Saturn's August 11, 2009, equinox. Scientists hope Cassini will remain active to map north-polar regions as the Sun illuminates them for the first time during the mission.

Saturn's rings shade portions of the planet's winter hemisphere, which greatly cools the upper atmosphere. Scientists expect to see seasonal change in the atmospheres of both Saturn and Titan during the mission.

Saturn has giant, long-lived thunderstorms larger than Earth and sports wind gusts as fast as 1,000 mph (1,600 km/h). Bright convective storms periodically flare up in certain regions. When storms are active, Cassini's instruments detect radio-noise bursts from lightning.

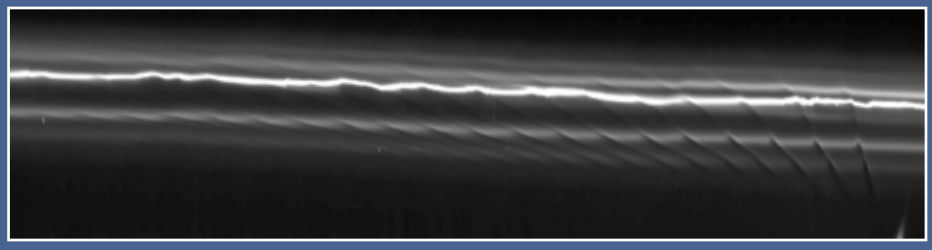
On January 23, Cassini's Radio and Plasma Wave Science (RPWS) instrument began detecting cracks, pops, and hisses similar to those heard on an AM radio during a terrestrial thunderstorm. "It is clear that this is the strongest lightning activity that we've seen yet with Cassini since it has arrived at Saturn," says the University of Iowa's Don Gurnett, principal RPWS investigator. "In fact, the flash rate even exceeds the rate observed by Voyager 1 back in 1980, and the intensities are at least as large, if not larger."

The energy that sustains larger atmospheric features may come from swallowing smaller storm systems. Ultimately, it's energy escaping from Saturn's interior, heat left over from its formation, that drives Saturn's weather. On Earth, it's the Sun's warmth that powers the weather. Saturn's meteorology seems topsy-turvy to us.

Ringed with complexity

▲ **DIFFERENT METHODS** reveal complementary information about Saturn's glorious rings. The top half of this composite is a natural-color mosaic showing the color and structure of Saturn's main rings. The bottom half is an image constructed from radio occultations, in which the ring particles blocked radio signals sent to Earth. The radio image reveals the range of particle sizes and densities in the rings. Brighter areas in the B ring indicate greater particle density there.

◀ **ACQUIRED JUST AFTER** Cassini entered Saturn orbit, this image shows details in the 200-mile-wide (325 km) Encke Gap in Saturn's bright A ring. Cassini reveals faint rings in the center of the gap. Pan, a 12-mile-wide (20 km) moon inside the gap, creates the wave-like structures on the gap's inside edge.

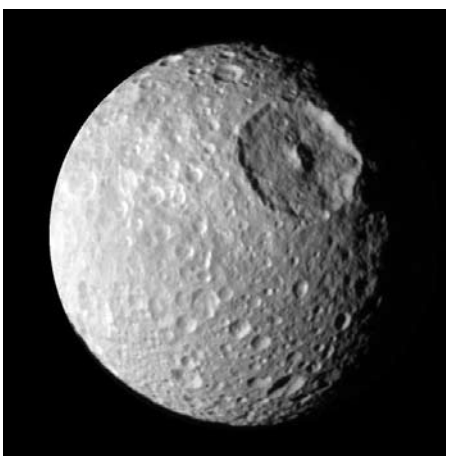


▲ **THIS F-RING** mosaic contains 15 images taken April 13, 2005, with Cassini's narrow-angle camera. The moon Prometheus (not shown) interacts with the ring particles and creates a channel once every 14.7 hours as it approaches the F ring. This scene shows a region 91,300 miles (147,000 km) along the ring.

◀ **THE COMPLEX RINGS** seem razor-thin when seen edge-on. At left, medium-size moon Dione lies just above the ring plane.

Fellowship of the rings

Saturn's glorious rings are what make this planet the solar system's jewel. Billions of ice particles, ranging from dust- to house-size, form the rings. Each particle orbits Saturn on its own path. Scientists are just beginning to address the question of how and when this complex system formed, but Cassini has provided definitive evidence for the origin of the tenuous E ring: plumes of water and ice venting from the south pole of the moon Enceladus.



MIMAS' GIANT Herschel Crater spans 88 miles (140 km). The impact that formed the crater nearly shredded the 247-mile-wide (398 km) satellite.

The main rings may have formed when an icy moon approached Saturn too closely and tidal forces or impacts with other objects tore it apart. Mimas and Hyperion each sport a single large crater nearly big enough to break apart the moon. Scientists estimate the total ring mass to be about that of Mimas. Perhaps a Mimas-size moon was torn apart by Saturn's tides, and some of the larger chunks struck other moons before mutual collisions among the debris ground the particles down into what we see in the rings. Or maybe the rings have always been there, unable to accrete into larger moons because of their closeness to Saturn.

Cassini has shown us several new moons in the ring gaps, and exotic ring structures associated with those moons. The small moon Prometheus produces streamers of particles as it nears the F ring every 14.7 hours. Prometheus dives more deeply into the F ring through 2009. This will create more extreme kinks, knots, and channels there for scientists to explore.

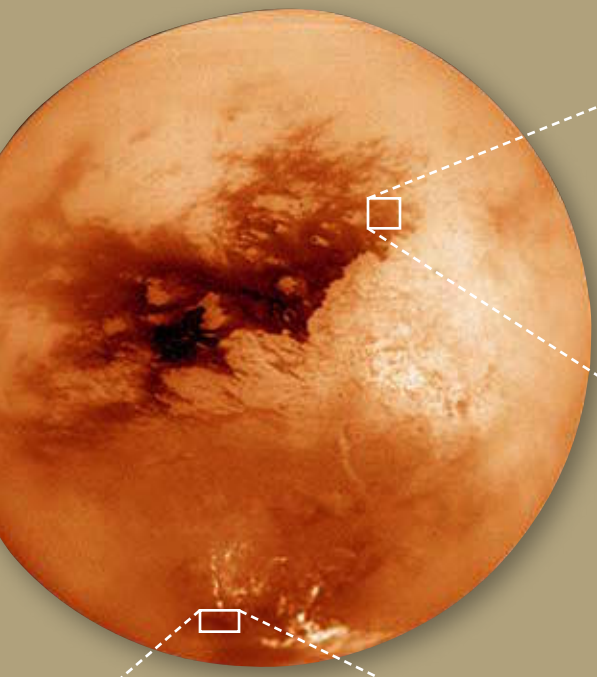
Cassini also uncovered a surprising increase in the amount of atomic oxygen at the edge of the rings, perhaps due to a recent collision there. Radio occultation measurements, which involve observing radio waves from Cassini as they pass through the rings to Earth, show that the B ring contains much denser concentrations of materials in a relatively thick core than either the flat A ring or the thin, wavy C ring. Perhaps the B ring has experienced a recent collision, too.

Icy satellites

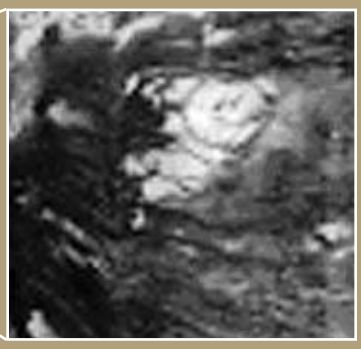
Throughout 2005, Cassini orbited in Saturn's equatorial plane, where the medium-size icy moons Mimas, Enceladus, Tethys, Dione, and Rhea reside. Mimas is a heavily cratered little world that doesn't appear to have experienced much internal activity.

But its neighbor Enceladus, which is only a little larger than Mimas, is covered with grooved terrain and appears to have erased many of its impact craters. The moon's south-polar region is especially active and geologically young. Fractures crisscross its white surface and expose dense blue ice. Last summer, several instruments on Cassini discovered giant plumes of water vapor venting from Enceladus' south pole.

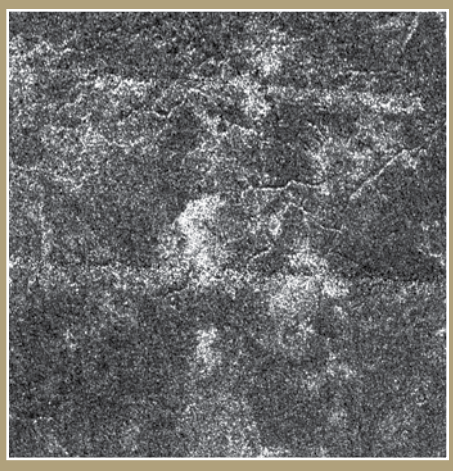
Planetary scientists had debated the origin of Saturn's broad but faint E ring since its 1967 discovery. Some Voyager-era investigators, reasoning that the moon resides in the



Mystery moon

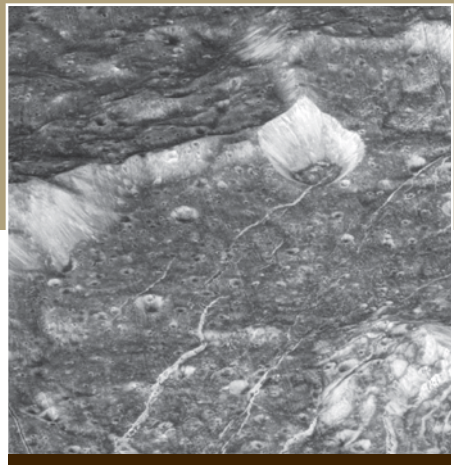


▲ **IS THIS** feature an icy volcano? Scientists suspect icy material reaches Titan's surface in much the same way molten rock reaches Earth's surface through volcanoes. The bright region in the inset may be ice that has forced its way to the surface and flows out onto it.



▲ **FLUIDS HAVE CUT** deep channels into Titan's icy surface in this Cassini radar image. The channels are roughly 0.6 mile (1 km) across and perhaps 650 feet (200m) deep. Some of these channels can be traced as far as 120 miles (200 km). NASA/JPL/RADAR TEAM

◀ **A FOOTPRINT-SHAPE** dark area near Titan's south pole in this infrared image may be a rare lake of liquid methane. Methane storm clouds brew in the region, so methane may be raining out of the sky and collecting in temporary lakes. This image is the best evidence yet for an open body of liquid on Titan.



DIONE'S 37-mile-wide (60 km) impact crater Padua Linea fills this image. Parallel linear grooves run across the terrain from top to bottom.

densest part of the ring and that it has a freshly condensed frost, suggested the possibility of active venting from Enceladus.

Cassini has dramatically confirmed this hypothesis: The plumes it detected extend more than 311 miles (500 km) above the surface. In July 2005, when Cassini passed just 109 miles (175 km) above the moon's south pole, several instruments directly detected the plume particles. "If it had been known beforehand that the plume would extend to that height, I'm not sure permission for a flyby this close would have been given," says team member Candice Hansen.

Enceladus seems to lack the most obvious energy sources to power this activity. It contains too little silicate rock for radioactive elements to supply the heat, as occurs inside Earth. And the moon isn't currently in an orbital configuration where tides can heat its interior. Perhaps in the past Enceladus was in such a configuration. Or perhaps the ice is ammonia-rich and melts at lower temperatures.

Tethys, Dione, and Rhea are also interesting worlds. Each surface, with its individual cratering and tectonic history, tells us a part of Saturn's story, and Cassini has returned high-resolution images of each. But Enceladus, with geysers apparently powered by near-surface pockets of liquid water, commands our attention.

Titan: shrouded in mystery

During the Voyager flybys of the 1980s, spacecraft cameras imaged Titan as a featureless red sphere: The moon's surface is shrouded by a photochemical haze generated in its dense atmosphere. Later, Earth-based telescopes penetrated the haze at infrared wavelengths. Scientists thought the dark and bright surface regions might be hydrocarbon seas and icy continents.

Cassini and Huygens have found no convincing evidence for either seas or lightning, yet the landscape is covered with channels carved by a runny fluid thought to be liquid methane. The Huygens probe measured an increase in methane vapor after it landed and heated the surface, and scientists think liquid methane may lie at shallow depths underground. Huygens also returned images of rounded cobbles, like those found in earthly riverbeds.

We now know the equatorial dark regions are more like sand seas — mostly covered by dunes that align themselves with the prevailing east-west winds. Unlike quartz sand on Earth or basaltic sand on Mars, Titan's sand probably comprises solid particles of organic gunk. This material precipitates from the upper atmosphere from chemical reactions powered by ultraviolet sunlight.

The bright regions do appear to be highlands. Titan shows few recognizable pristine landforms, such as impact craters or volcanoes. Most of the highlands appear to be either a chaotic jumble or heavily eroded. Channels and worn impact craters testify to lots of methane rain, yet, except for the south pole, Titan has only a few feeble transient clouds.

Ultraviolet light quickly and irreversibly transforms the moon's methane into solid organic particles. So, Titan must have a present methane source. Some think it resides in a large near-surface reservoir of

Icy Old Faithful

▲ **CASSINI SKIRTED** Enceladus' south polar region in July 2005. Cassini found areas near the striking bluish fractures ("tiger stripes") were warmer than the rest of the icy moon.

▶ **VIEWED FROM** the surface, Enceladus' jets of water and ice might resemble terrestrial geysers, as in this artwork. RON MILLER

liquid methane, perhaps mostly underground except for polar-region lakes. Others think the gas vents from the subsurface and may create transient clouds. But Cassini has not yet seen clouds associated with a landform that looks volcanic.

The outer limits

Saturn's oddest moons lie beyond Titan. They have eccentric and tilted orbits, not near-circular ones in the equatorial plane of Saturn like the inner moons. Some of them may be captured objects — adopted children rather than progeny of the nebula from which Saturn formed. First outward from Titan is Hyperion, which spins with a chaotic tumbling motion. It is surprisingly large for an object with such an irregular shape. It has an unusually low density, and its surface resembles a sponge. Scientists think Hyperion was smacked by an impactor that removed most of the moon and showered the inner saturnian system with debris.

Farther outward is Iapetus, perhaps stranger even than Hyperion. Planetary scientists have long known Iapetus has a leading hemisphere that is nearly black and a trailing hemisphere that is quite bright. Iapetus, like many satellites, is tidally locked, so the same hemisphere always faces the primary planet. As a result, there are leading and trailing hemispheres with respect to the orbit.

There were competing theories for the origin of this brightness dichotomy, but Cassini has confirmed the idea that the dark material collected on the moon's leading hemisphere is dust shed by Phoebe and other moons. Cassini found something even stranger about Iapetus: It has a flattened shape and a bulging ridge around its equator, like a walnut shell. Julie Castillo from JPL and her colleagues suggest this shape arose early in the moon's history thanks to a rapid spin and a warm, deformable interior. They believe the interior was briefly warmed by short-lived radioactive materials. If correct, this model places strong constraints on the formation time of Saturn (4.566 billion years ago) and the early evolution of planetary systems in general.

Still farther from Saturn lies a family of irregularly shaped moons in odd orbits, the largest of which is Phoebe. Many previous moons of the Phoebe family have been obliterated by collisions, often with Phoebe. Phoebe's composition has proven to be primitive and icy, which indicates this is a body that formed in the frigid outer solar system. There were many such bodies in the early solar system, but most were ejected by gravitational interactions with the planets. Now, only those in the Kuiper Belt beyond Neptune, such as Pluto, remain.

Cassini's primary mission ends in 2008, but planning is underway for a 2-year extended mission. What would scientists do with this bonus time? They are debating options like maximizing opportunities to study active Enceladus and Titan.

Sooner or later, Cassini will probably be commanded to impact Saturn. This move is designed to protect any microbial life that, however unlikely, might exist on Titan or Enceladus. Meanwhile, the Huygens probe sits on Titan's surface. Perhaps one day a methane flood will wash it away, or dunes will bury it under organic particles.

But, halfway through the primary mission, the Cassini/Huygens legacy is already certain: Data from this ambitious mission will keep scientists busy for decades to come. The scientific payoff aside, Cassini/Huygens is a monument to how far human ingenuity can take us — and a reminder of how much we have left to explore.

ONLINE EXTRA Find out scientists' plans for Cassini at www.astronomy.com/toc.

{ COSMOLOGY }

Where is the universe heading?

To find out how it all ends, scientists need to understand what makes up the universe. /// BY JAMES TREFIL

Everything and everywhere began about 14 billion years ago in the Big Bang. Since then, a massive expansion of space-time has carried galaxies far away from each other. After American astronomer Edwin Hubble discovered this expansion in the 1920s, the question of how the universe will end has been on astronomers' minds.

On one hand, the expansion could reverse, in which case, all the matter in the universe would come together again — the Big Crunch. Cosmologists call this scenario a "closed" universe. On the other hand, the expansion could go on forever, leading to a bleak, cold, and empty future — the Big Chill. Cosmologists call this possibility an "open" universe. The border between these two futures, between closed and open, fire and ice, is called a "flat" universe. In a flat universe, the expansion goes on forever but coasts to a halt after an infinite amount of time.

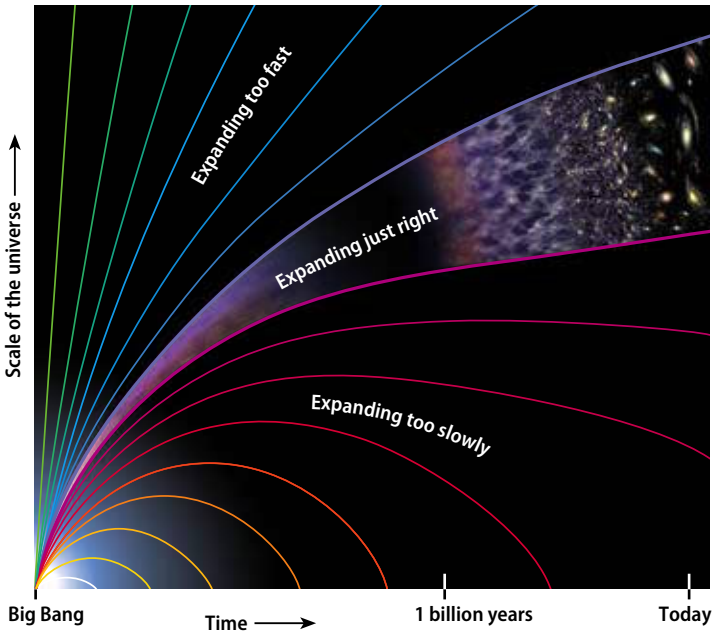
Cosmic tug-of-war

The Big Bang theory took hold in the mid-20th century (the name actually was coined by the theory's opponents). An easy way to think about the expansion is to imagine throwing a ball up from Earth's surface. As the ball travels upward, Earth's gravitational force acts on the ball, slowing it down and eventually

James Trefil *is the Clarence Robinson professor of physics at George Mason University and a frequent contributor to* Astronomy. *His latest book is* Human Nature: A Blueprint for Managing the Earth — By People, For People *(Times Books, 2004).*

GRAVITATIONAL LENSING provides astronomers with direct evidence of dark matter's existence. The massive cluster Abell 1689 must contain mass we cannot see. The luminous galaxies in the cluster do not have enough mass to bend light from a distant galaxy (the arcs of blue light in this image). NASA/H. FORD (JHU)/G. ILLINGWORTH (UCO/LICK)/N. BENITEZ (JHU)/M. CLAMPIN (STScI)/G. HARTIG (STScI)/THE ACS SCIENCE TEAM/ESA

The universe's perfect parameters



OUR GOLDILOCKS UNIVERSE has just the right parameters. If the universe had a higher percentage of dark energy, it would expand so fast that stars and galaxies wouldn't form (cool colors). If the universe had no repulsive force driving the expansion, it would reverse into the Big Crunch (warm colors). *ASTRONOMY*: ROEN KELLY

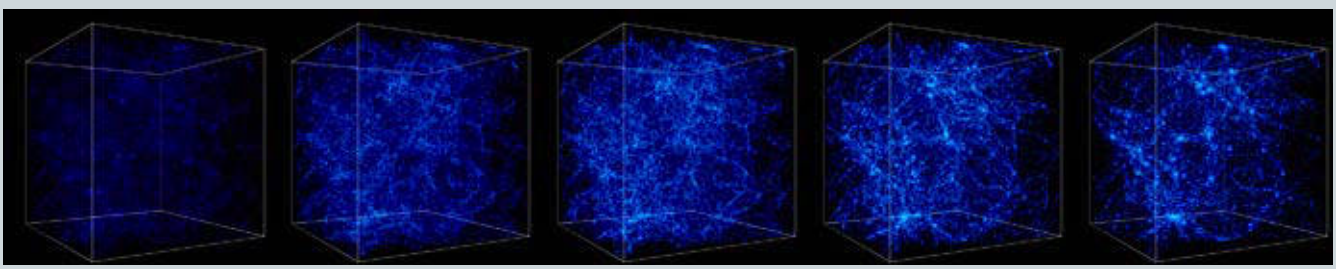
turning it around and bringing it back to the surface. Throw the ball fast enough — 7 miles per second (11 kilometers per second) — and the ball will escape Earth's gravitational pull and keep going. In this case, gravity will still slow the ball down, even if the force doesn't stop it.

In just the same way, the theory predicts, a galaxy in the Hubble expansion will feel the gravitational pull of all the other galaxies in the universe. Like the ball, the galaxy will slow down. The only question is whether the gravitational force is strong enough to stop the expansion. The momentous question of the universe's fate comes down to a simple query: Does a distant galaxy move at a speed equivalent to its escape velocity? The answer depends on the magnitude of the gravitational force that slows the expansion. This, in turn, depends on how much stuff is out there.

Astronomers usually phrase this question in terms of the average density of matter in the universe. The density corresponding to a flat universe — the boundary between open and closed — is called the critical density and is customarily denoted by the symbol Ω_c. This density corresponds to about one proton per cubic meter of space. This may not seem like much, but remember that there are a lot of cubic meters out there.

The invisible mass

If you count up all the stuff astronomers see — stars, dust clouds, and other kinds of ordinary, or baryonic, matter — it totals about 4 percent of the critical density. (Count only stars and planets, and



DARK MATTER determined how cosmic structure evolved over the universe's early history. Computer simulations show a tendency for smaller objects to clump into larger structures, which implies cold dark matter dominated the early universe.

SIMULATIONS AND VISUALIZATIONS BY ANDREY KRAVTSOV (U. CHICAGO) AND ANATOLY KLYPIN (NMSU)

WHAT IS THE MISSING MASS?

Astronomers know roughly 22 percent of the universe is dark matter. But *what* is it?

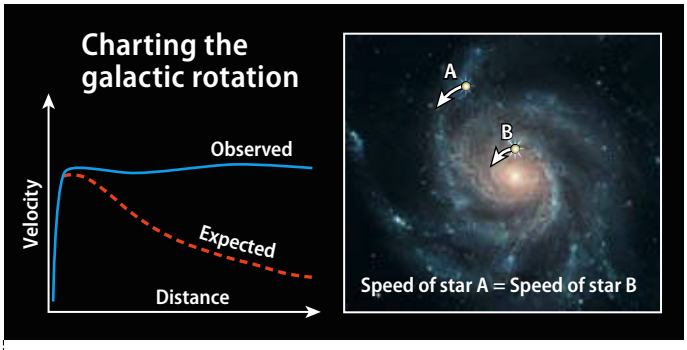
One possibility is hot dark matter (HDM) — or neutrinos. In the early universe, these particles had extremely high velocities, close to the speed of light. HDM particles' random motions wiped out small density fluctuations in the early universe's matter distribution. Once the particles cooled enough to form structures, only large (supercluster-size) structures could form.

This is the "top-down" scenario of structure formation. HDM was the leading theory a few decades ago, but observations of the universe's large-scale structure have since ruled out top-down as the main process. Scientists now believe small structures combined to form larger structures. Neutrinos aren't the main contributor to the mysterious matter, but they may be a small amount of the overall dark matter, on the order of a few percent.

The most likely candidate is cold dark matter (CDM). These particles had slower velocities in the early universe; therefore, fluctuations in the matter distribution stayed intact. Small structures could form early on and combine into larger objects over time — this is the "bottom-up" scenario. According to scientists, two hypothetical elementary particles are the main candidates for CDM.

The neutralino is a particle predicted by supersymmetry (SUSY), a theory that each known particle has a massive, neutral, and stable "superpartner" with a different spin. Neutralinos interact by the gravitational force, as does all matter, and by the weak nuclear force; hence, they're called weakly interacting massive particles, or WIMPS. The other CDM particle is the axion, an extremely light particle with no spin or electric charge.

Scientists think that, given the neutralino's large mass, it's the best candidate. Current experiments such as those at the Soudan Mine in Minnesota, and the Gran Sasso National Laboratory in Italy, are trying to detect dark matter. In 2007, CERN, the European Organization for Nuclear Research, will begin operating the Large Hadron Collider (LHC). The LHC's energies will reach those of the theoretical SUSY particles, and, therefore, LHC will either confirm or disprove SUSY. We may know soon what dark matter is. Scientists are keeping their fingers crossed. — *Liz Kruesi*



ROTATION CURVES of galaxies don't look like what astronomers predicted. Instead of a decrease in velocity at greater distances, observers saw a plateau, so star B's speed is equal to star A's speed. Something — dark matter — must hold these distant stars in the galaxy, or they'd be flung away. *ASTRONOMY*: ROEN KELLY; GALAXY: NASA/ESA

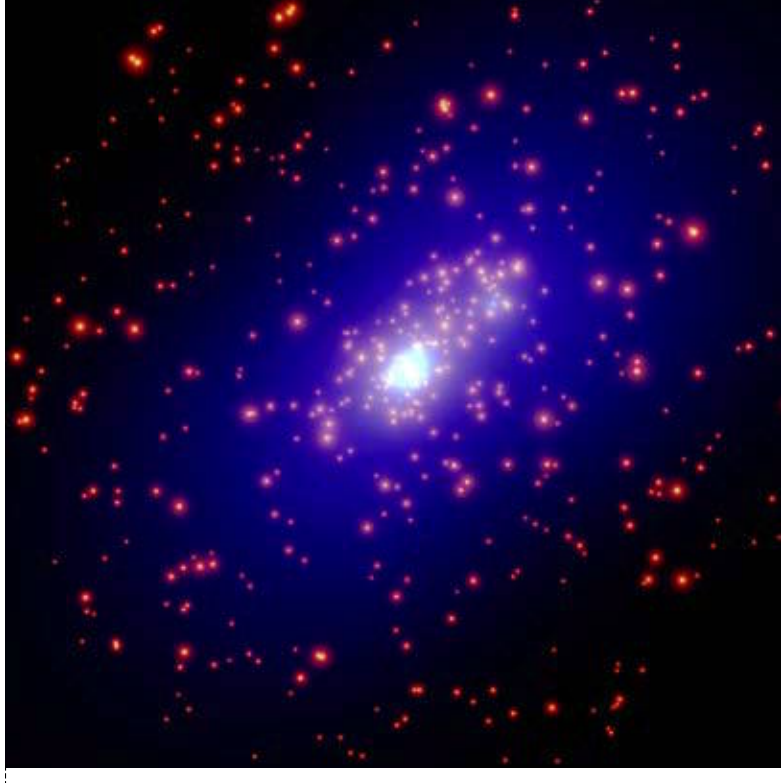
this number drops to half a percent.) If you count only baryonic matter, you would conclude the universe is open. Starting in the 1980s, however, more theorists began to argue that the density of the universe had to be exactly Ω_c. This led a number of astronomers to search for the missing mass needed to "close" the universe.

Vera Rubin from the Carnegie Institution of Washington solved part of this puzzle in the 1970s. Rubin was looking at rotation curves of distant galaxies. If you think of the spiral shape of a galaxy like the Milky Way, you realize the galaxy as a whole is rotating. In fact, the Sun completes one circuit about every 250 million years. One way of characterizing this rotation is to determine how fast the material in the galaxy is moving as a function of how far away from the center that material is.

Close to the center of a galaxy, gravity locks objects together; the galaxy rotates like a wheel. A star farther away from the center has a higher velocity than one closer in. Think of this part of the galaxy as a merry-go-round. Farther out, you come to a region where all of the matter moves at the same velocity, no matter how far away from the center it is. Like runners on a curved track, the outer stars will gradually fall behind the inner ones, because they're traveling at the same speed and have a greater distance to travel. This feature of galactic rotation gives the spiral arms their characteristic bent appearance.

When you get far away from the galaxy's center, you should see a third kind of rotation. If a piece of matter is far enough away from the center, the entire galaxy can be viewed as a single massive point. There, the matter's rotation around that point should be like the rotation of planets around the Sun. Sixteenth-century astronomer Johannes Kepler discovered that the farther a planet is from the Sun, the slower it moves. It takes Jupiter about 10 Earth-years to orbit once, partly because it has farther to go than Earth, but mainly because it is moving slower. This so-called Keplerian rotation is a signal that the observed body is well away from the galaxy's main mass.

Rubin discovered that no matter how far away you get from the center of a galaxy — even when you look at tenuous hydrogen gas far from the spiral arms — you never see Keplerian rotation. This means that even in the galaxy's outskirts, stars are locked into the galaxy's mass. The only way for this to happen is for the visible galaxy to be surrounded by a sphere, or halo, of something else — something not visible, something dark. This stuff is called "dark matter."



A MAP of how mass is distributed in galaxy cluster cl0024+1654 shows how dark matter is the glue that holds the cluster together. This image is a composite of a computer-generated dark-matter map (blue) created from gravitational data, and a Hubble Space Telescope image showing the galaxies (red). ESA/NASA/JEAN-PAUL KNEIB (OBSERVATOIRE MIDI-PYRÉNÉES/CALTECH)

By definition, dark matter neither emits nor absorbs radiation, but we can see the effects of the gravitational force it exerts. Imagine that Earth was covered continually by clouds. We would still know the Moon exists (by observing tides, for example) even though we couldn't see it.

We now know that over 90 percent of material in galaxies like the Milky Way is dark matter, and there's a higher percentage in stellar clusters. As you read this, physicists are trying to detect dark matter. One such experiment involves this matter sweeping by as Earth moves in its orbit. We may soon know what sort of stuff dark matter is (see "What is the missing mass?" at left).

For the fate of the universe, however, it is enough to know that if we add dark matter to our census of ordinary matter, the density of the universe comes to about a third of Ω_c.

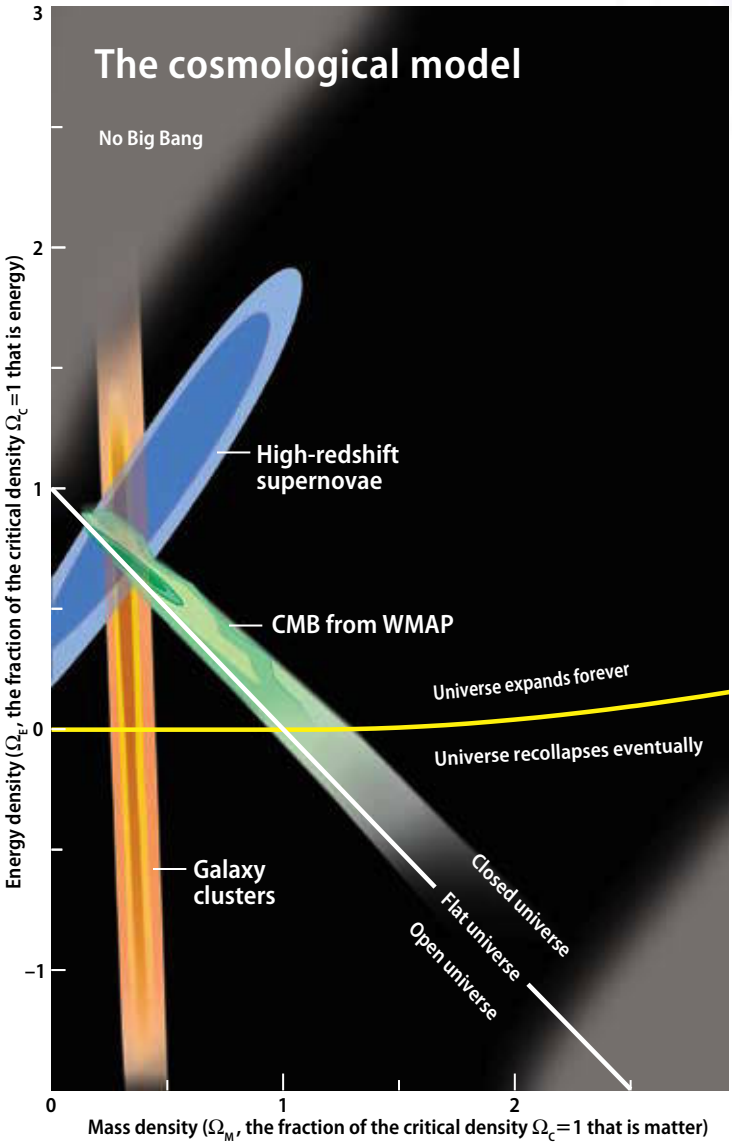
Finding a better tool

By the 1990s, astronomers had pushed the known mass of the universe closer to the critical density. Some argued dark matter spread thinly in intergalactic space would make up the rest of the missing mass and give theorists what they wanted. Others, such as Saul Perlmutter (leader of the Supernova Cosmology Project) of the University of California at Berkeley and Brian Schmidt (leader of the High-Z Supernova Search) of the Australian National Observatory, took a different approach.

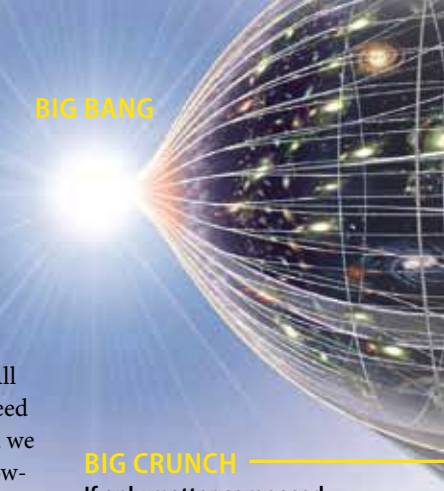
When you look at a distant galaxy, you are seeing the galaxy as it was when that light was emitted. The light reaching us from a galaxy 10 billion light-years away, for example, tells us what that galaxy was like 10 billion years ago.

We measure the speed at which a galaxy is receding from us by redshift: how much the light emitted by atoms in that galaxy is

THE SLOAN DIGITAL SKY SURVEY (SDSS) imaged this galaxy before (left) and after a supernova exploded. The supernova tally is growing at a rapid pace, which is good news for cosmologists trying to solve the dark-energy riddle. SDSS-II COLLABORATION



BY COMPILING DATA from different observations, cosmologists form a better idea of our universe's composition and future. Scientists compared data from the cosmic microwave background, distant supernovae, and galaxy clusters to determine a preferred model. All observations converge at a universe with a mass density of 0.3 and energy density at 0.7. This suggests the universe is flat and will expand forever. *ASTRONOMY*: ROEN KELLY, AFTER SAUL PERLMUTTER



BIG BANG

BIG CRUNCH

If only matter composed our universe, or if dark energy disappears, gravity could force the universe to collapse. The universe would end in a reverse of the Big Bang; it would become an incredibly dense, hot singularity. This is a closed universe.

shifted toward the red end of the spectrum — the larger the shift, the higher the speed. This means that when we look at the galaxy in our example, we are seeing how fast the universe was expanding 10 billion years ago. All we have to do is compare this speed to its current expansion rate, and we can tell how quickly gravity is slowing the expansion. From this, mathematics tells us whether the expansion will continue or stop.

Measuring the so-called deceleration parameter is easy to describe, but a little harder in practice. The problem arises when we ask how we know a particular galaxy is really 10 billion light-years away.

An astronomer looking at a distant galaxy is a little like a person standing on a dark highway and watching a car's tail lights recede into the distance. He or she can find out how fast the car is going by measuring the redshift of the light, but in the darkness, there is no way to get the distance.

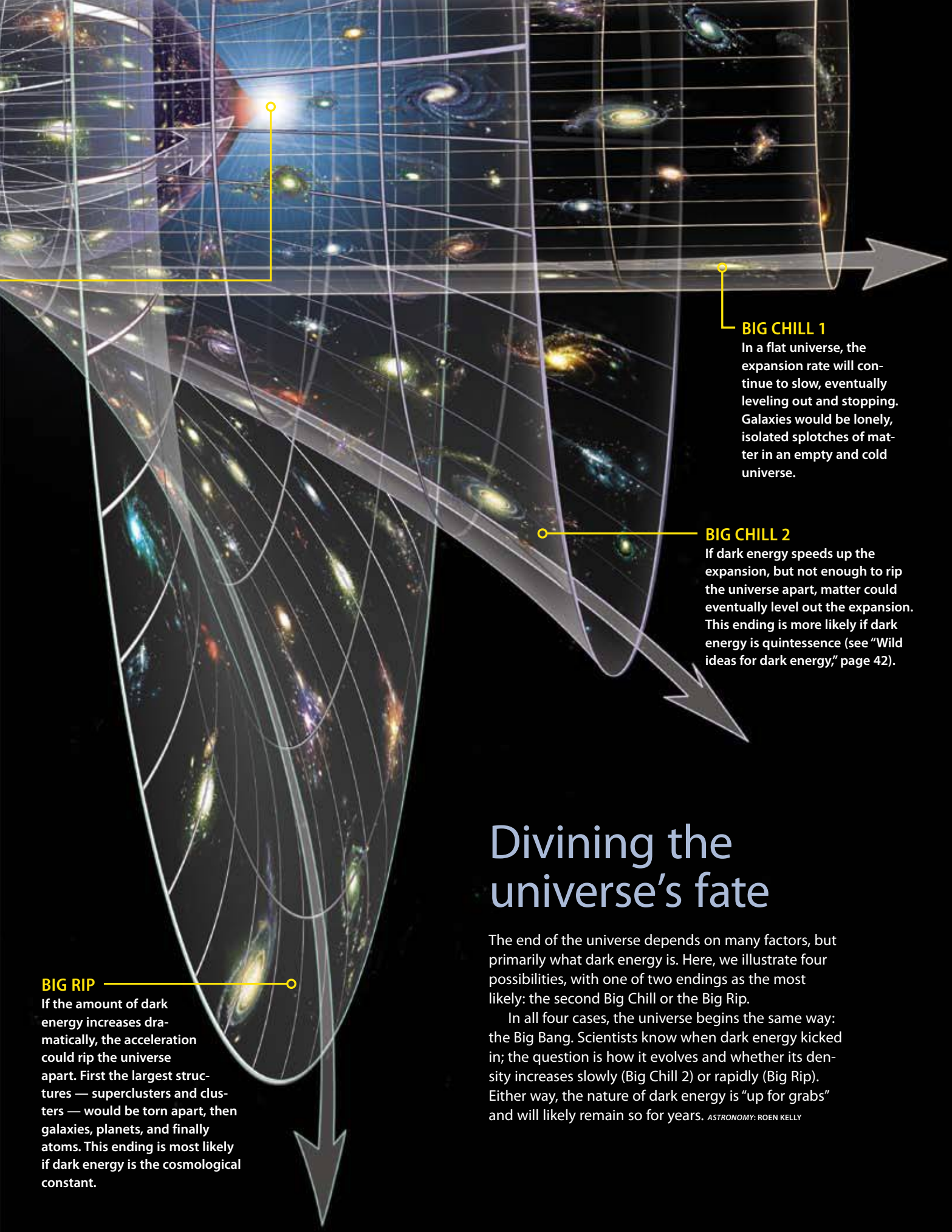
Astronomers since Edwin Hubble have dealt with this problem by using a standard candle — an object in the distant galaxy whose total output of light is known. Then, by measuring the amount of light you receive and noting how the light has spread, you can figure out how far away the source must be. For example, if we knew the car's tail lights in our example were rated at 10 watts, we could measure the amount of light we see and deduce how far away the car is.

Hubble, using the 100-inch (2.5-meter) Hooker telescope at Mount Wilson Observatory near Pasadena, California, was able to pick out individual stars to use as standard candles. Knowing the fate of the universe, then, comes down to finding a standard candle that will allow us to get the distance to galaxies so far away that we can't see individual stars, even with our best telescopes.

The final surprise

Enter the type Ia supernova. This event occurs in a specific type of star system. It begins with a binary system in which one star, not too different from the Sun, has gone through its life cycle and shrunk down to a cinder about the size of Earth. Astronomers call this a white dwarf. The white dwarf pulls material (mainly hydrogen) away from its normal-size companion until a layer several feet thick builds up on its surface. When this layer gets thick enough, the whole thing explodes like a giant hydrogen bomb. For a period of weeks, this supernova can outshine the entire galaxy where it resides.

By watching these events in nearby galaxies, whose distances from Earth are known from other techniques, astronomers learned that the longer the light from the supernova lasted, the brighter it was initially. This allows us to construct a standard candle. We watch a distant supernova, see how long it shines, and calculate how much light it is emitting. Comparing this to the amount of light we actually receive gives us the distance.



BIG CHILL 1
In a flat universe, the expansion rate will continue to slow, eventually leveling out and stopping. Galaxies would be lonely, isolated splotches of matter in an empty and cold universe.

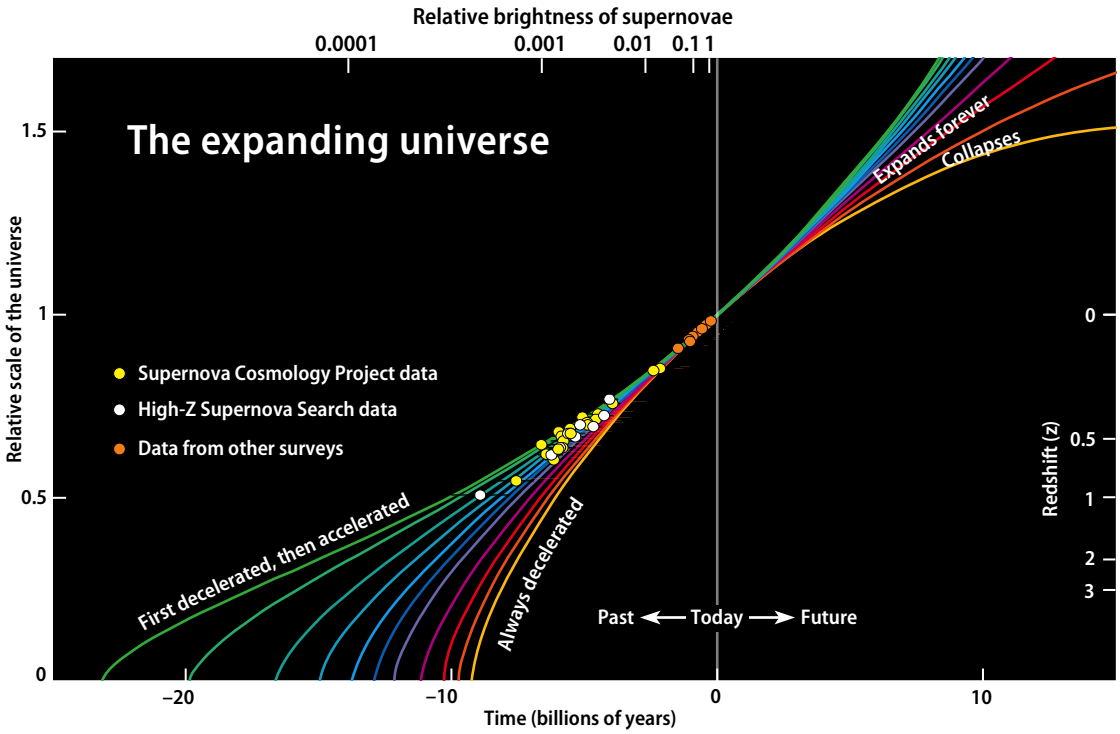
BIG CHILL 2
If dark energy speeds up the expansion, but not enough to rip the universe apart, matter could eventually level out the expansion. This ending is more likely if dark energy is quintessence (see "Wild ideas for dark energy," page 42).

BIG RIP
If the amount of dark energy increases dramatically, the acceleration could rip the universe apart. First the largest structures — superclusters and clusters — would be torn apart, then galaxies, planets, and finally atoms. This ending is most likely if dark energy is the cosmological constant.

Divining the universe's fate

The end of the universe depends on many factors, but primarily what dark energy is. Here, we illustrate four possibilities, with one of two endings as the most likely: the second Big Chill or the Big Rip.

In all four cases, the universe begins the same way: the Big Bang. Scientists know when dark energy kicked in; the question is how it evolves and whether its density increases slowly (Big Chill 2) or rapidly (Big Rip). Either way, the nature of dark energy is "up for grabs" and will likely remain so for years. *ASTRONOMY:* ROEN KELLY



THE COSMIC "S" CURVE shows the universe's expansion history. Data from both the Supernova Cosmology Project and the High-Z Supernova Search teams have led to the discovery that the universe's expansion is accelerating.

Once the data were placed on possible expansion histories, scientists were able to say the universe's expansion was decelerating in the past and switched to accelerating. As scientists discover more supernovae and put more data points on this map, they will be able to piece together the universe's fate. *ASTRONOMY*: ROEN KELLY, AFTER SAUL PERLMUTTER

WILD IDEAS FOR DARK ENERGY

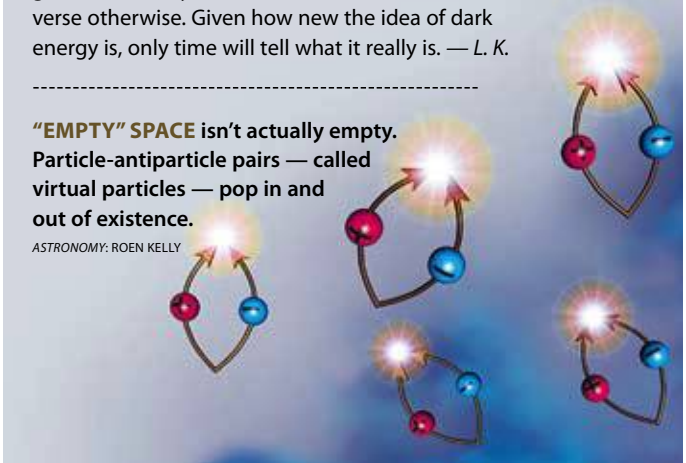
When scientists discovered the universe's expansion is accelerating, this threw them for a loop. The force behind the acceleration, dark energy, is more mysterious than dark matter, and dark energy's composition will decide the universe's fate. Two leading theories of dark energy are the cosmological constant (vacuum energy) and quintessence.

Albert Einstein, in his static universe model, created a term called the cosmological constant. This constant is a repulsive gravitational force, to counter matter's attractive gravitational force. The idea behind the cosmological constant — or vacuum energy — is space isn't really empty. Instead, a smoothly distributed, persistent background energy permeates the cosmos, with particle-antiparticle pairs popping in and out of existence. As the universe expands, the density of the vacuum energy stays constant.

The problem with this theory arises when we calculate how much vacuum energy should exist in the universe. Using what scientists know about vacuum energy (from quantum field theory), they estimate there should be 10^{120} times the observed amount.

The other option is called quintessence. This is a dynamic field that interacts with matter and changes with time.

Or maybe Einstein's theory of general relativity — that matter changes the geometry of space-time and gravity is a result of this curved geometry — is wrong? This is highly unlikely, however, as general relativity fits so well in the model of the universe otherwise. Given how new the idea of dark energy is, only time will tell what it really is. — *L. K.*

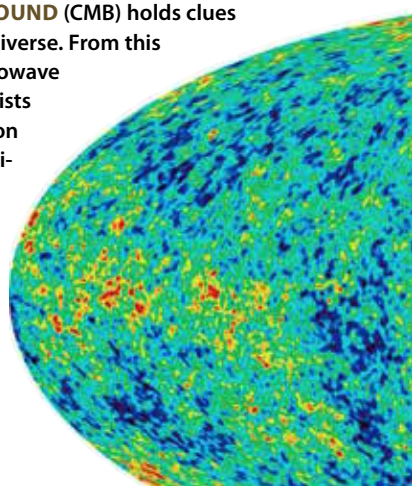


"EMPTY" SPACE isn't actually empty. Particle-antiparticle pairs — called virtual particles — pop in and out of existence. *ASTRONOMY*: ROEN KELLY

Both the Supernova Cosmology Project team and the High-Z Supernova Search team used this approach and studied dozens of type Ia supernovae. When each team published its first results in 1998, there was a fair amount of alarm in the cosmological community. Against all expectations, both groups found the most distant galaxies are receding from Earth *more slowly* than nearby ones. In other words, the Hubble expansion is faster today than it was billions of years ago. The expansion is accelerating!

The scientific community's reaction to this bombshell revelation provides a textbook case of how new discoveries are received. Most people went about their business and ignored the result, hoping it would be proved wrong. A few took a gamble and treated the new results seriously, asking what sort of universe could display this kind of behavior. As time went on, more supernovae were measured, and the observational results became more precise — scientists now have data from roughly 300 distant supernovae. Cosmologists began to realize there is something in the universe they hadn't known about up to this point — something capable of counteracting the attractive force of gravity.

University of Chicago astrophysicist Michael Turner coined the term "dark energy" to describe whatever it is that gives rise to this new force. We have known for a century that $E=mc^2$, so we can convert into a mass the amount of dark energy needed to produce

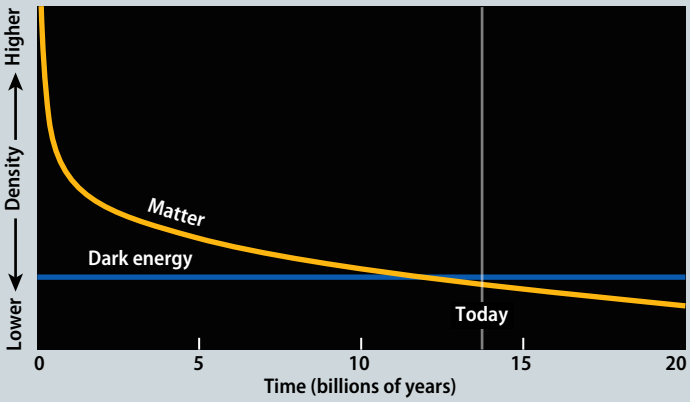


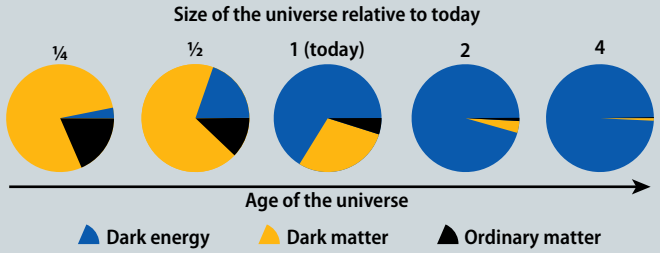
THE COSMIC MICROWAVE BACKGROUND (CMB) holds clues to the composition and age of the universe. From this map produced by the Wilkinson Microwave Anisotropy Probe (WMAP), cosmologists inferred the universe is flat, 13.7 billion years old, and contains 4-percent ordinary matter, 22-percent dark matter, and 74-percent dark energy. The CMB's temperature is 2.725 Kelvin, with red splotches only a three-thousandth of a kelvin warmer than average, and blue splotches three-thousandth of a kelvin cooler. NASA/WMAP SCIENCE TEAM

THE COSMIC COINCIDENCE

We seem to live in a "special" time in the universe, when matter and dark energy are almost equal. Matter dilutes away as space expands — the density of matter in the early universe was much higher than it is now. If dark energy is the cosmological constant, or vacuum energy, then its density stays constant. The relative abundance of these two densities changes dramatically over the history of the universe.

Why are they comparable now? Scientists aren't sure, but a few ideas are that we're just lucky, or we live in one of many universes where everything — the laws of physics — just happened to be perfectly tuned. — *L. K.*





(TOP RIGHT) OVER TIME, matter — shown here as dark matter because the universe contains far more dark than ordinary matter — dilutes away, and dark energy stays constant (if the cosmological constant is dark energy). For an unknown reason, they are almost equal now.

(RIGHT) THE RELATIVE AMOUNT of dark energy (if it's the cosmological constant), dark matter, and ordinary matter changes. At one-quarter the universe's present size, dark matter dominated. When the universe grows to 4 times its current size, dark energy will dominate.

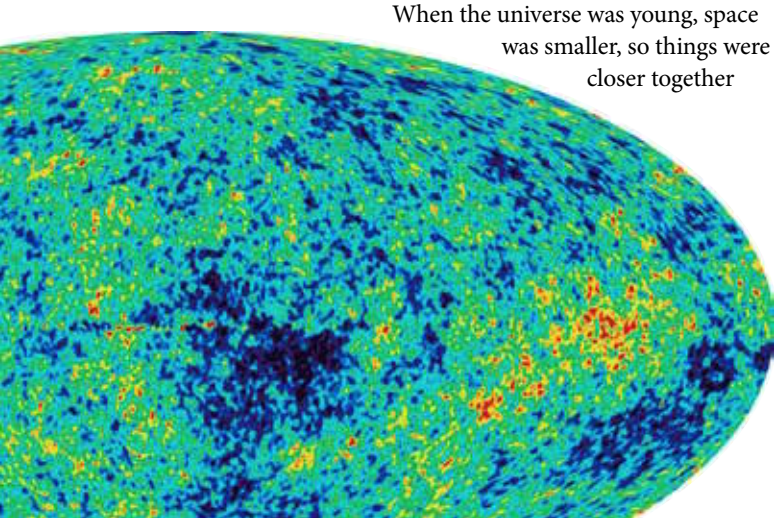
BOTH ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

the observed expansion. When we do so, we find the density of dark energy comes to about two-thirds of Ω_c.

So, there you have it. We now know the basic ingredients of the universe — a few percent of ordinary matter, about 22-percent dark matter, and 74-percent dark energy. We know pretty well what ordinary matter is, and we have narrowed the possibilities for dark matter to a few particles whose existence theory predicts. The nature of dark energy, on the other hand, is pretty much up for grabs — Turner calls it the most important scientific question of the 21st century.

Is the end in sight?

Dark matter and dark energy play different roles in the universe's expansion. Dark matter produces most of the ordinary gravitational attraction in the universe — acting as a brake on the expansion. Dark energy, on the other hand, is a repulsive force and blows things apart — acting as the gas pedal for expansion. The history of the universe (both the past and future) comes from a competition between the two, between the brake and accelerator.



When the universe was young, space was smaller, so things were closer together and gravity won — the expansion slowed down. Then, when the universe was about 5 billion years old, ordinary and dark matter were spread thinly enough for the effects of dark energy to take over. Since then, the expansion has been accelerating. This switch between slowing down and speeding up shows up in redshift measurements of light from galaxies at different distances from us.

So, which will win in the future, the brake or the gas pedal?

The answer depends on what dark energy is. If it turns out the amount of dark energy in the universe is constant, then its density will drop as the expansion proceeds. In this case, the current acceleration will be just a passing phase in the life of the universe; the expansion eventually will slow as gravity puts on the brakes. We would then come back to the same choices we started with — closed, open, or flat, with the most likely choice being the last.

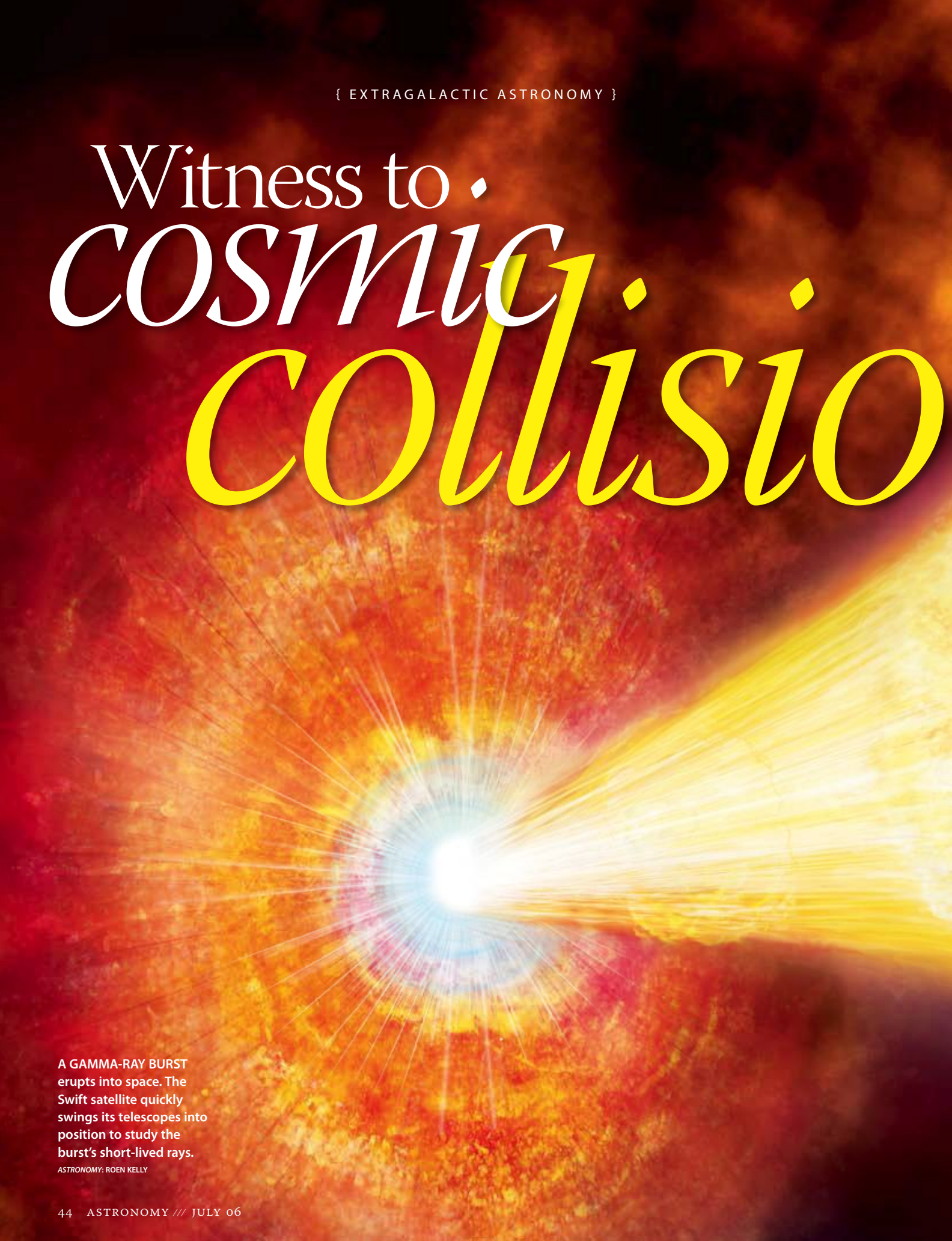
If the overall density of dark energy stays constant, however, then the gas pedal will stay down, and the universe's expansion will accelerate in the future. The universe's matter will spread out, and space will be cold and empty — the Big Chill.

But what if the universe tromps on the gas pedal and the acceleration speeds up, leaving gravity in the dust? If the amount of dark energy increases with time, the future will be spectacular. The disruptive force would begin by tearing galaxies apart, then stars, and then — if it got bigger than the forces that hold molecules together — planets and any people who are around at the time. This scenario is the Big Rip.

It never fails. Just when you think you're on the verge of a definitive answer to a crucial question like the fate of the universe, you find yourself with a set of new — and more fascinating — questions you never imagined you'd be asking.

ONLINE EXTRA To learn about future experiments designed to probe dark energy's mysteries, visit www.astronomy.com/toc.

Witness to cosmic collisio



A GAMMA-RAY BURST erupts into space. The Swift satellite quickly swings its telescopes into position to study the burst's short-lived rays.

ASTRONOMY: ROEN KELLY

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NASA's Swift mission helps astronomers unlock the 35-year-old mystery of what causes short gamma-ray bursts.

/// BY ROBERT ZIMMERMAN

On November 20, 2004, NASA launched the Swift satellite into orbit. During its 2-year mission, Swift has observed and studied elusive gamma-ray bursts, the most powerful explosions in the universe. In its first 6 months of operation, NASA's Swift mission detected a range of gamma-ray bursts, including one short burst too near the Sun for its telescopes to slew to. Since then, it has detected more than 120 bursts and observed many in unprecedented detail.

Near midnight May 9, 2005, the NASA Swift satellite's gamma-ray Burst-Alert Telescope (BAT) came to life. From the constellation Coma Berenices, about 4° from the north galactic pole, a short but powerful burst of gamma radiation had hit the craft's detector.

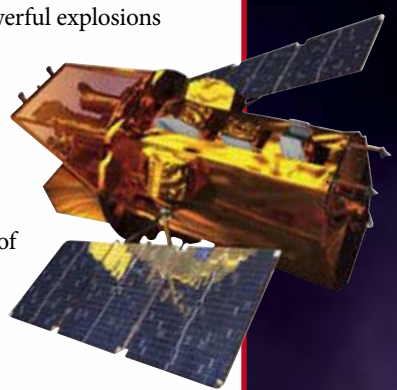
Within seconds, the spacecraft swung around to aim its X-ray Telescope (XRT) and Ultraviolet-Optical Telescope (UVOT) at the source. In just over a minute, Swift was snapping its first pictures of a burst.

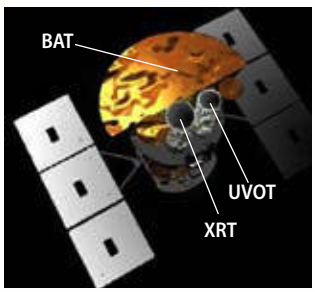
The mystery of GRBs

Gamma-ray bursts (GRBs) have been one of astronomy's most enduring mysteries since their discovery in the early 1970s. Their ephemeral appearance, usually less than 100 seconds and often shorter than a second, made it impossible to spot these events in any wavelength other than the initial blast of gamma rays — telescopes could not slew to them before the event subsided. Without additional GRB data, there was no way to determine a burst's distance, location, or strength.

By the 1990s, theories purporting to explain GRBs' origin filled scientific journals. Two ideas were especially intriguing, as they called for very large and powerful explosions occurring at cosmological distances. One theory proposed the bursts result from an unusual supernova explosion, the sudden collapse of a massive star's core. The second theory suggested the merger of two neutron stars, or a neutron star and black hole, causes the bursts.

The launches of the Hubble Space Telescope in 1990 and the Italian





THE SWIFT satellite prepares for its Gamma-Ray Burst Mission in this artist's illustration of the spacecraft. NASA launched Swift and its retinue of telescopes November 20, 2004.

NASA/SONOMA STATE UNIVERSITY/ AURORE SIMONNET

Robert Zimmerman *is an astronomy and space-exploration writer and speaker who lives in Washington.*

A NEUTRON-STAR merger, shown here as a 12-frame sequence, likely causes short gamma-ray bursts. Astronomers believe a neutron-star-black-hole merger is another possibility for creating these elusive bursts. The Swift satellite is designed to detect and record GRBs in real time.

ALL IMAGES: NASA/D. BERRY

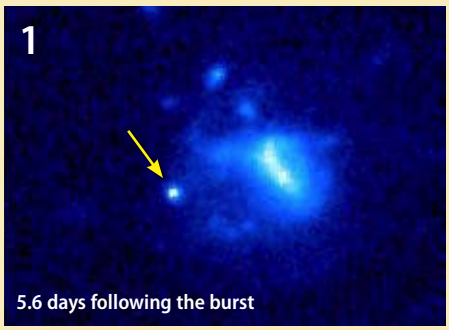
Gravitational fields of 2 neutron stars begin to interact.

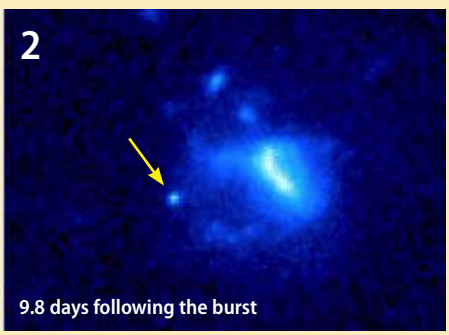
The stars get closer and begin to heat up.

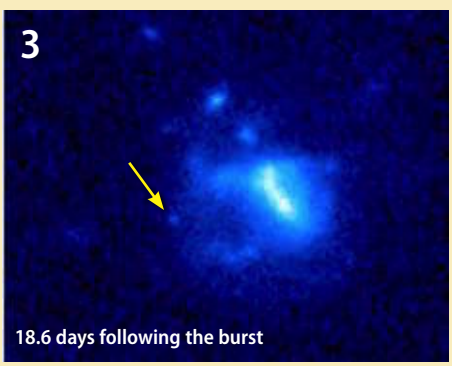
The spiraling stars begin to merge.

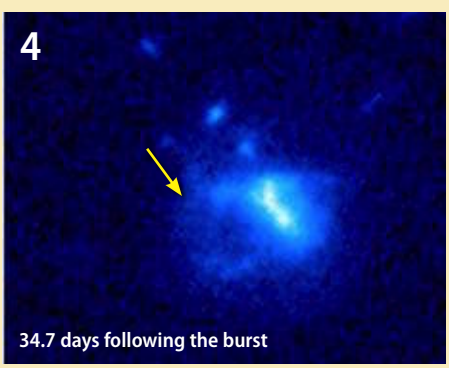
Two neutron stars become one.

Coming together is an explosive event.









CATCH A FADING LIGHT

Gamma-ray burst GRB 050709 represents a landmark in GRB history. It is the first short burst to be imaged in visible light and its redshift calculated.

NASA's High Energy Transient Explorer (HETE-2) satellite detected GRB 050709 July 9, 2005. HETE's Wide-Field X-ray Monitor and Soft X-ray Cameras determined the burst's location — information crucial to determining the GRB's distance.

Thirty seconds after the initial 1/10-of-a-second burst came X-ray emission lasting 2½ minutes. The Chandra X-ray Observatory subsequently imaged GRB 050709's X-ray afterglow.

Brian Jensen of the University of Copenhagen and his colleagues followed up with ground-based observations of GRB 050709 using the 60-inch (1.54 meter) telescope at the European Southern Observatory in La Silla, Chile. The group confirmed detection of the GRB's fading optical afterglow.

NASA's Hubble Space Telescope also imaged the GRB's optical counterpart 5.6, 9.8, 18.6, and 34.7 days following the burst. The images at left were taken on each of those days, respectively.

The Gemini North Telescope in Hawaii observed what is likely the GRB's host galaxy at redshift z=0.16, which corresponds to a distance of about 2 billion light-years.

Given GRB 050709's relative closeness to Earth, many scientists theorize a neutron-star-black-hole merger or, more likely, a merging of two neutron stars, resulted in a cosmic collision that created this short GRB. — *R. Z.*

NASA'S HUBBLE Space Telescope captured these visible-light images of GRB 050709's afterglow. The GRB (arrow) faded after 34 days.

DEREK FOX/PENNSYLVANIA STATE UNIVERSITY

Space Agency's BeppoSAX satellite in 1996 made it possible to pin down and localize longer bursts. Not only were long bursts — those lasting longer than 2 seconds — taking place at high redshifts many billions of light-years away, but some appeared to be associated with ultra-energetic supernovae ("hypernovae"). After 30 years of speculation, it now appeared many long bursts occurred when a star collapsed and exploded to form a black hole.

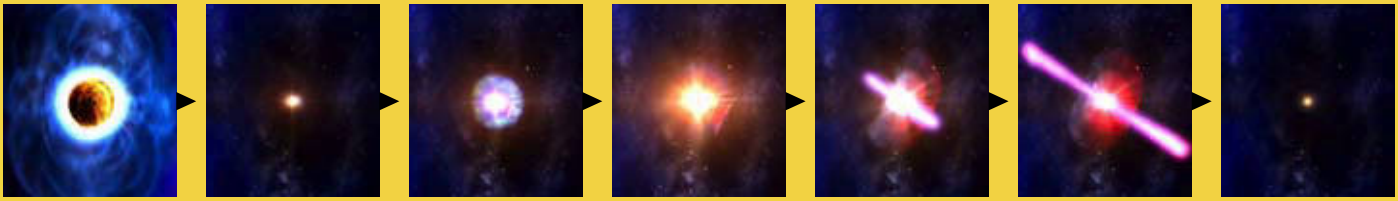
For bursts shorter than 2 seconds, however, the mystery remained. Because these bursts are so fleeting, their afterglows disappeared by the time telescopes could turn to the burst locations. And without an afterglow — X rays, visible light, and radio waves emitted when the radiation from the GRB's shock wave collides with the surrounding medium — it was impossible to determine a GRB's location, distance, or structure precisely.

NASA planned Swift's gamma-ray mission in 2001 specifically to address these challenges. Comprising three telescopes — BAT, XRT, and UVOT — Swift can respond almost instantly whenever its gamma-ray detector senses a GRB. The satellite immediately slews to the GRB's location. The XRT and UVOT attempt to image the rapidly fading afterglows from the shortest bursts.

The shortest GRB

On May 9, Swift took only 6 seconds for its telescopes to slew to GRB 050509B — one of the shortest GRBs ever detected, lasting a mere 40 milliseconds. Less than a minute later, Swift picked up the burst's X-ray photons. Despite the burst's brevity, Swift's XRT captured 11 X-ray photons from the GRB's afterglow — the first time scientists observed a short GRB in a wavelength other than gamma rays.

Scientists estimate GRB 050509B — the first short GRB to be precisely located — is near a bright elliptical galaxy at redshift 0.225, which indicates a distance of 3 billion light-years.



The merged object emits a gamma-ray burst.

The explosion's shock wave expands.

The shock wave continues expanding outward.

Jets begin to form at the shock wave's poles.

Jets become more defined as they continue to expand.

A well-defined jet is seen from the side.

A face-on jet's brightness wanes.

Even so, no telescope, including Swift, captured an optical counterpart of the May 9 burst, so it was not possible to determine the GRB's redshift. However, the X-ray afterglow pinpointed the burst's location, placing it smack inside a galaxy cluster and within 9.8" of a massive, bright elliptical galaxy.

Spectroscopy of the galaxy revealed a low redshift of 0.225, implying a distance of 3 billion light-years. If the burst were linked to this galaxy, it would be one of the closest known GRBs.

As Paul O'Brien of the University of Leicester, England, noted at a July 26, 2005, meeting of the Swift science team at the Goddard Space Flight Center in Greenbelt, Maryland, "We had to be patient, and on May 9 patience paid off."

On July 24, two days before the Swift team came together at Goddard to report on the satellite's status, Swift picked up a second short gamma-ray burst. To the astronomers' delight, this second short burst exhibited features similar to the first.

THE SHORT BURSTS' relative closeness to Earth favors the theory of a neutron-star merger.

All of the short GRBs' features were fundamentally different than those found with long bursts, and all of them seemed to fit the theory of a neutron-star merger as the cause.

Long bursts have so far been found inside small, young, star-forming galaxies where astronomers would expect to find many supernovae. Long bursts also occur at an average distance of about 7 billion to 10 billion light-years — a time when the universe was much younger and producing many more young stars.

The two short bursts, however, were associated with red, old elliptical galaxies with no star-forming regions — places where supernovae do not often occur. Both bursts were located offset from their host galaxies rather than inside them. Both had low redshifts, indicating a distance of about 3 billion light-years.

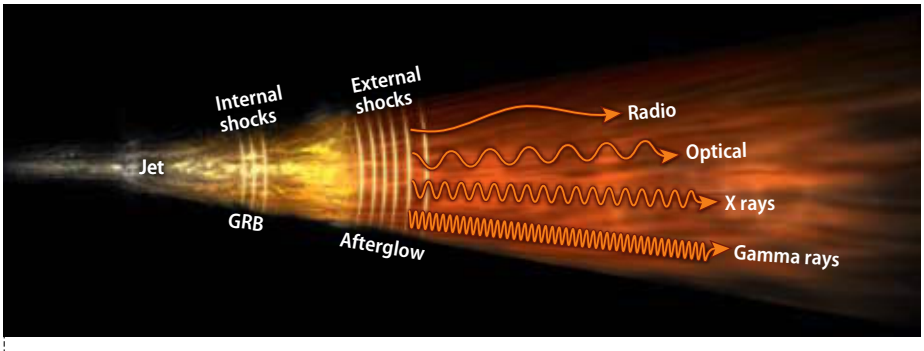
These differences strongly suggest the short bursts formed by a merger of either two neutron stars or a neutron star and a black hole, not by the core collapse of a massive star.

It takes a long time for two neutron stars to spiral together. Swift astronomers expected to find these old neutron binary systems in an old, red galaxy. Moreover, the astronomers expected the explosion that forms a neutron star would kick the star out of its host galaxy. The offset locations of both bursts suggest an origin related to merging neutron stars.

The short bursts' relative closeness to Earth favors the theory of a neutron-star merger. Such mergers require a great deal of time to evolve and develop, so they are more likely to occur in more recent times.

Also, both bursts were extragalactic. A nearby Milky Way event such as a starquake — an explosion on the surface of a neutron star — is ruled out.

These preliminary data support the compact-object-merger theory for the short bursts found so far. "An elliptical galaxy like this is, in fact, a very good environment to find mergers of compact binaries containing neutron stars or black holes," notes Craig Sarazin of the University of Virginia.



A GRB JET expands into the surrounding interstellar medium, emitting radiation as it travels. As two neutron stars (or a black hole and a neutron star) merge, internal shocks result in a burst of gamma rays. External shocks produce an afterglow observed at radio, optical, X-ray, and gamma-ray wavelengths. *ASTRONOMY:* ROEN KELLY

Swift's potential

Swift's future looks bright. The telescope's ability to respond almost instantaneously to events allows it to study astronomical phenomena in which speed is essential.

GRBs occur randomly, sometimes in flurries followed by pauses. This allows Swift time to perform other research.

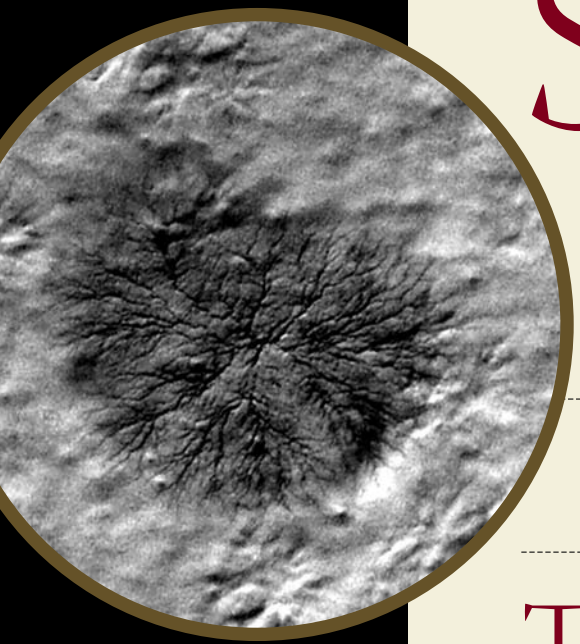
Swift captured the afterglow of several supernovae, including SN2005cs, detected June 28, 2005, in the Whirlpool Galaxy (M51). These data help constrain the nature of supernova explosions, which are reliable "standard candles" — objects with well-determined absolute magnitudes.

Swift's number-one priority, however, remains the study of gamma-ray bursts. The satellite will continuously monitor the sky for the duration of its mission, tracking every burst. By then, astronomers might be able to say they have solved one of astronomy's oldest mysteries.

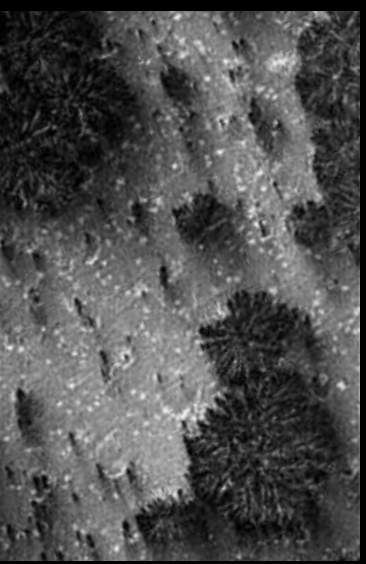
ONLINE EXTRA Learn about other spacecraft behind GRB discoveries at www.astronomy.com/toc.

Spiders on Mars

Branching patterns on Mars' south pole link the planet's climate to its most prominent landforms. /// BY FRANCIS REDDY



SPIDERS can occur alone, as with this 1,750-foot-wide (533m) specimen, or in groups so dense their branching channels overlap. NASA/JPL/MSSS



LARGE, DARK SPIDERS populate this Mars Global Surveyor image near 82° south latitude. Spiders are depressions that occur in flat, southern polar terrain. This image is 1.7 miles (2.8 km) across. NASA/JPL/MSSS

There's something unusual at Mars' south pole. Since its 1997 arrival, NASA's Mars Global Surveyor (MGS) spacecraft has returned hundreds of images of features dubbed "spiders" by mission scientists. Spiders, which occur only in the south polar region, average about 985 feet (300 meters) across and appear to be depressions in which ragged ravines diverge from a common center.

In 2000, Hugh Kieffer at the U. S. Geological Survey (USGS) in Flagstaff, Arizona, suggested spiders result from a geyser-like process made possible by climatic conditions around the Red Planet's south pole. He and his colleagues have been refining this idea ever since. They suspect conditions during the south polar winter may allow the martian equivalent of "black ice" to form there. If true, this may explain one of Mars' most enduring observational puzzles. It may also demonstrate a dramatic coupling between martian geology and meteorology, for the south pole's climatic conditions appear to owe their existence to three of Mars' most prominent features.

Spiders' superficial resemblance to vegetation moved science-fiction writer Arthur C. Clarke to compare them to banyan trees. "I'm now convinced that Mars is inhabited by demented landscape gardeners," Clarke quipped in June 2001. Spider devotee Greg Orme of Queensland, Australia, is so enthralled, he's placed every image he can find — together with some unorthodox explanations — on a web site called Martianspiders.com.

Although most scientists discredit any connection between living organisms and spiders, they, too, find the structures intriguing. It's the exception that tells the geological story, and spiders are one of a handful of strange south-polar landforms scientists are at odds to explain. They include patches of dark, circular spots (informally called "Dalmatian spots"), spots surrounded by halos ("fried eggs"), and dusky, aligned, wedge-shape markings ("oriented fans").

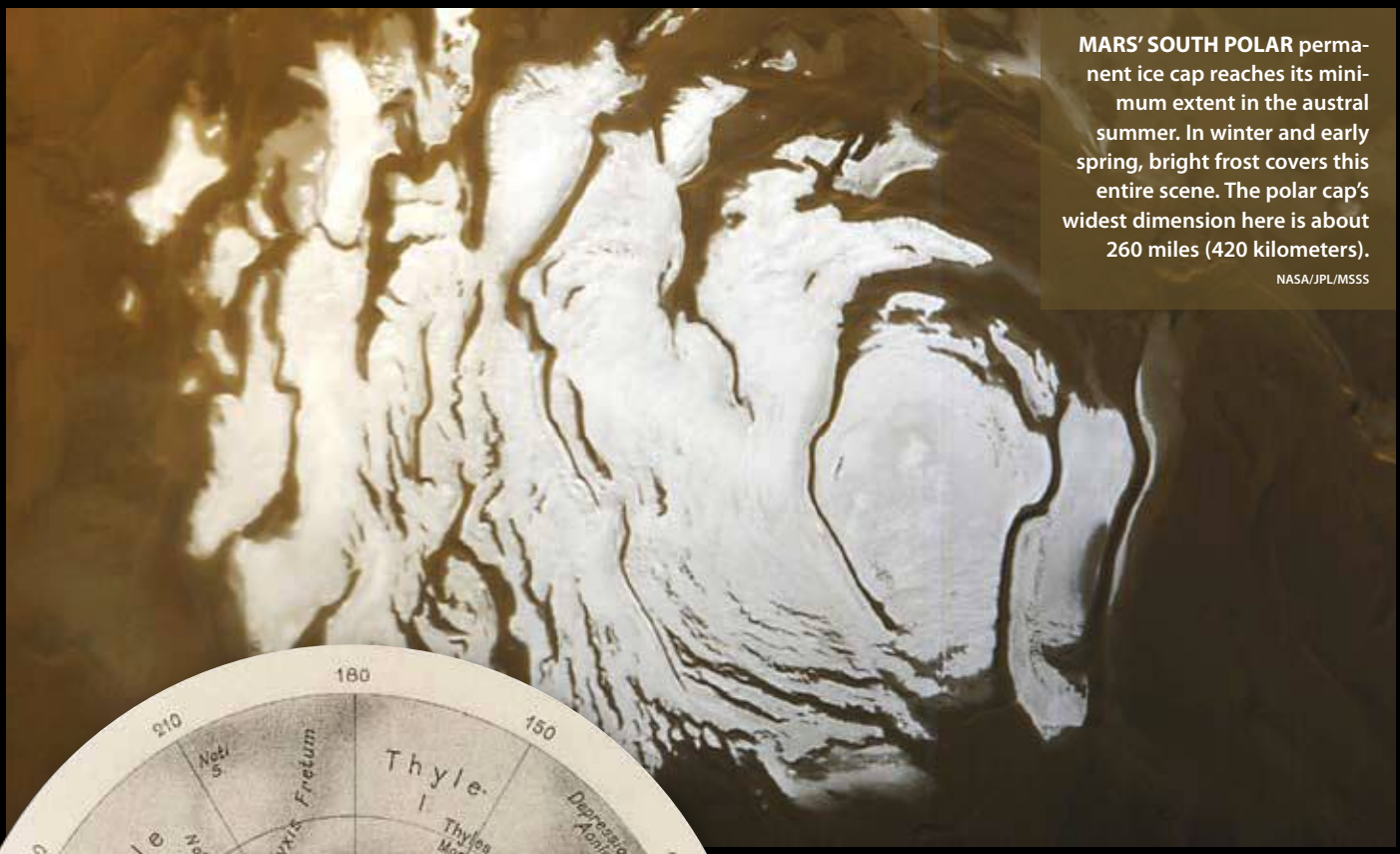
"We're still scratching our heads over how these things are forming," says Anthony Colaprete of NASA's Ames Research Center in Mountain View, California. "They're unlike anything we have on Earth."

"These features are very peculiar and extremely interesting, with some very real implications for polar processes on Mars," says USGS Flagstaff scientist Tim Titus. "And it's the polar processes that drive the climate."

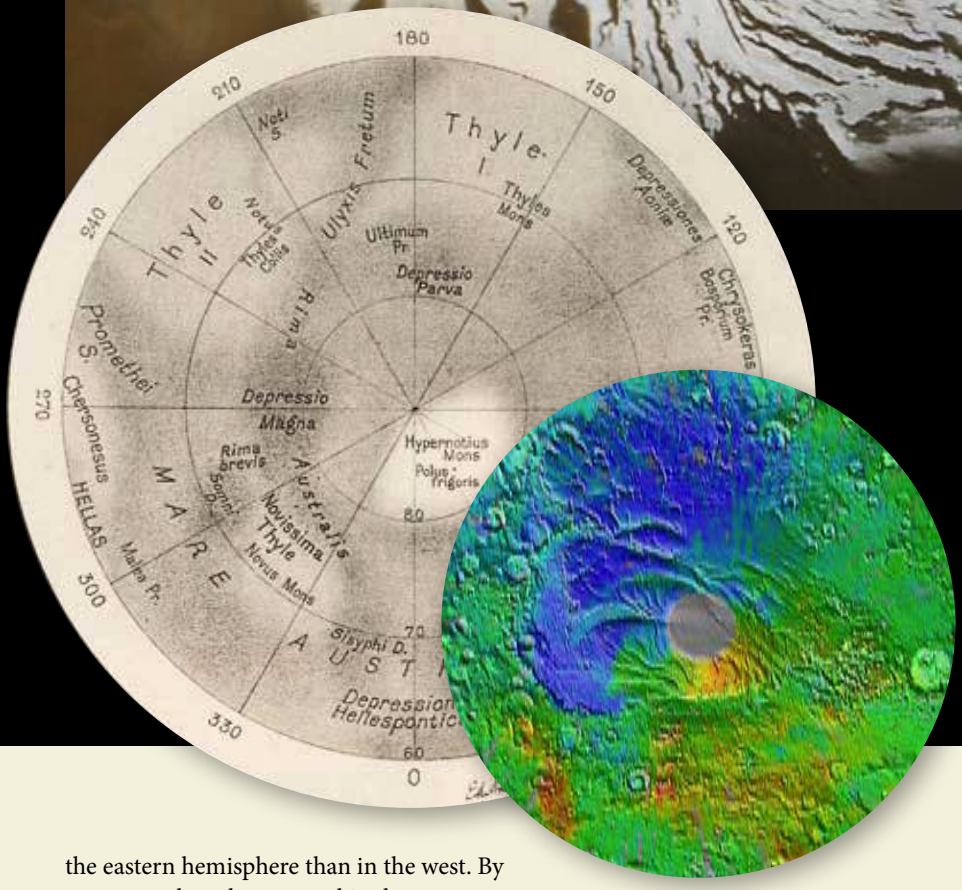
Tales from the cryptic region

Late 19th- and early 20th-century Mars-watchers noticed that the southern ice cap makes a peculiar retreat when spring arrives. The seasonal cap recedes faster in

Francis Reddy *is an associate editor of* Astronomy.



MARS' SOUTH POLAR permanent ice cap reaches its minimum extent in the austral summer. In winter and early spring, bright frost covers this entire scene. The polar cap's widest dimension here is about 260 miles (420 kilometers). NASA/JPL/MSSS



◀ **EUGÈNE ANTONIADI** mapped Depressio Magna (1909) and Depressio Parva (1929) as Mars' South Polar Cap retreated in spring. Features he thought were depressions roughly occupy the cryptic region. LINDA HALL LIBRARY OF SCIENCE, ENGINEERING & TECHNOLOGY

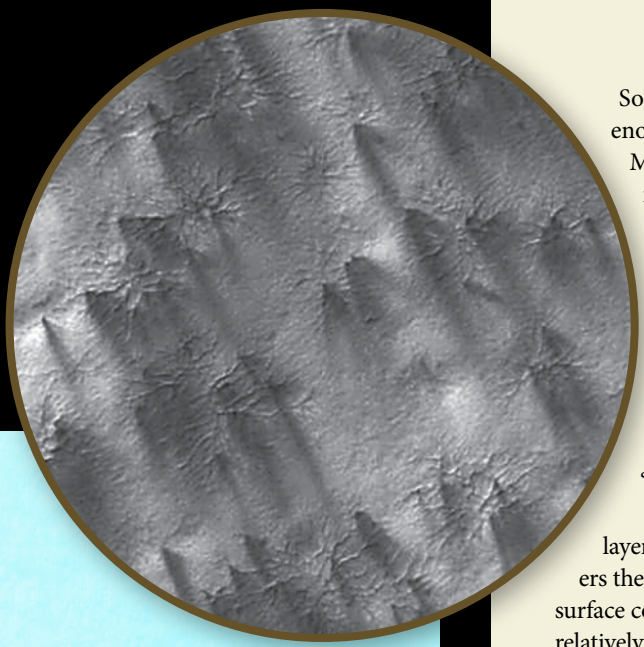
◀ **MARS GLOBAL SURVEYOR** captured early springtime reflectivity and topography around the planet's south pole. Warm colors show the locations of bright ice, frost, and snow, while the original cryptic region Kieffer and Titus defined appears deep blue. Gray indicates no reflectivity data. A. COLAPRETE ET AL. 2005, NASA/JPL/MOLA SCIENCE TEAM

the eastern hemisphere than in the west. By summer, when the seasonal ice has vanished, the permanent cap sits to one side of the planet's south pole.

Percival Lowell, the astronomer who popularized the idea of martian canals, described a dark rift that grew along a feature named Rima Australis. This fit with Lowell's erroneous idea that the melting polar cap formed a sea. Later, Eugène Antoniadi mapped dark regions, which he thought were depressions that developed as the seasonal polar cap receded. But no one could explain why Mars' southern ice fields make their strange, asymmetrical retreat, or why the permanent cap isn't centered on the geographic south pole.

Fast-forward to March 1999, when MGS began its primary mapping mission. Because the spacecraft orbits the planet nearly pole to pole, its instruments can study high-latitude regions in detail. Kieffer and Titus noticed something odd on the polar region's eastern side — an area roughly corresponding to the depressions Antoniadi mapped.

The Thermal Emission Spectrometer (TES) aboard MGS shows that much of the terrain on the south pole's eastern side has a springtime surface temperature of –193° F (–125° C). Temperatures this low on Mars are usually associated with carbon dioxide (CO_2) that freezes out of the atmosphere as dry ice. But at the same time, TES readings indicate the surfaces at this temperature are dark, reflecting less than 40 percent of incident sunlight.



DEFROSTING TERRAIN in some areas around Mars' south pole takes on a malignant visage. A connection between spiders and what appears to be windblown dust is clear in this 1.5-mile-wide (2.4 km) MGS scene. *Inset:* Oriented fans align with local wind conditions and appear to originate from spiders. The scene is 0.9 mile (1.4 km) wide. NASA/JPL/MSSS

So, here was a puzzle: a surface cold enough to be ice but dark enough that MGS cameras appeared to be imaging bare ground. When Kieffer and Titus examined Viking Orbiter thermal measurements from the 1970s, they found the area displayed the same pattern of temperature and reflectivity. "I could kick myself for not noticing it in Viking data years ago," Kieffer says. He calls this zone the "cryptic region."

Kieffer suggests a 1-yard-thick layer of nearly transparent CO_2 ice covers the cryptic region. On Earth, when the surface cools below freezing but the air stays relatively warm, a thin layer of transparent ice — sometimes called "black ice" — may form on the ground. A similar process can occur on Mars. About 25 percent of Mars' atmosphere freezes out during the polar night, usually as dry-ice snow. But, under the right conditions, CO_2 can freeze directly onto the surface as a layer of clear ice.

A pure CO_2 ice slab is about as transparent to sunlight as any ice can be. Kieffer thinks the cryptic region's puzzling behavior makes sense if spacecraft are viewing the martian surface through a thick, clear ice layer. But he also reasons the ice must contain a similar amount of dust as the atmosphere it condenses from. He suggests the ice undergoes a self-cleaning cycle in early spring. Sun-warmed dust particles heat the ice they're in contact with until the CO_2 returns to the gaseous state. Gravity pulls each dust particle downward. The ice beneath each particle turns to vapor, so the dust falls farther and the gas pocket above it refreezes. This process continues until dust tunnels all the way through the slab.

Kieffer thinks a patina of bright frost coats the clear ice during winter. As the springtime Sun rises higher in the sky, this reflective veneer quickly disappears from the cryptic region. But once light strikes the slab ice, it easily penetrates to the surface and warms the ground. CO_2 ice contacting the ground turns into a layer of gas beneath the frozen slab. "The ice is actually levitating on a thin layer of gas," Kieffer explains. Because the gas has no outlet, pressure rises beneath the floating slab.

Kieffer thinks this pressure can rise high enough to crack the ice and spew gas and dust. He calculates a vent 1-yard across could blast material at speeds greater than 112 mph (180 km/h). In 2000, when Kieffer identified and christened the cryptic region, he argued that spiders, oriented fans, and Dalmatian spots all relate to venting of subsurface gas and dust through cracks in clear CO_2 ice.

Mapping spiders

If Kieffer is right, spiders should occur only where TES observations indicate slab ice exists. So, in August 2003, a team led by Sylvain Piqueux of Caltech in Pasadena, California, examined the relationship between spiders and CO_2 slab ice. The researchers broadened the definition of the cryptic region, which in late winter encircles the entire south polar cap (SPC). As spring progresses, the region shrinks to the area Kieffer and Titus originally recognized.

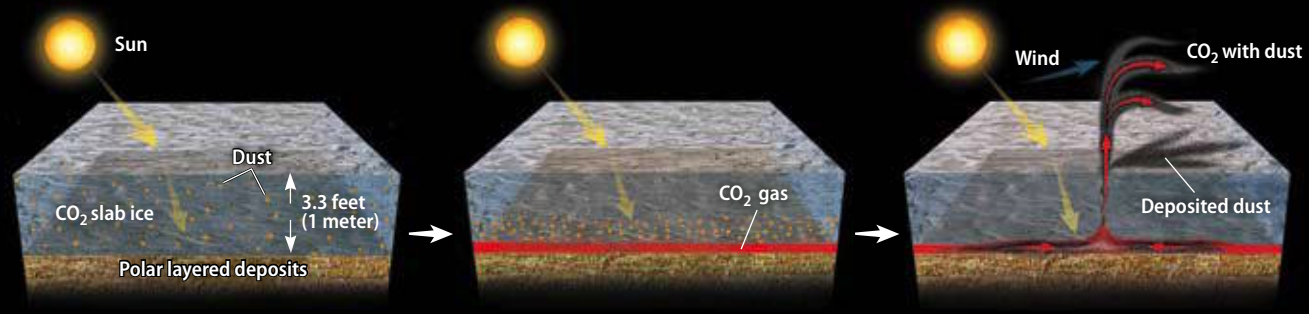
The team showed spiders are unique to the SPC, even though other regions exhibit cryptic (dark and cold) conditions, so there's more to spider formation than just the presence of slab ice. Piqueux and his colleagues showed spiders form only in areas thought to contain slab ice, occur only on polar layered deposits, and occur in association with oriented fans.

"WE'RE DEALING WITH physics for which there's no terrestrial experience." *— Hugh Kieffer*

All of this seems to support Kieffer's idea. Once the ice ruptures, and trapped CO_2 escapes, the outrushing gas sweeps up loose material and carries it up through the breach. As the jet scours the surface, it erodes the converging ravines characteristic of spiders. A dusty plume rises from the vent and punches into the atmosphere. Dust settles out of the plume as it drifts downwind, creating dark fans of fallout on the clear ice. This scenario also explains why spiders aren't seen in other regions where slab ice seems to exist. Without a good supply of loose surface material, the escaping gas can't erode those ragged channels.

No one knows how long it takes a spider to form, but Piqueux and his team think it may be years. Images show there isn't much change in spiders from one martian year to the next, which suggests they may recur in

How martian spiders form



ESCAPING subsurface CO_2 may carve spider channels. *Left*: Sun-warmed dust moves downward through a CO_2 ice slab; this keeps the ice clear. *Center*: Sunlight heats the martian surface and adjacent ice turns into gas. *Right*: The pressurized CO_2 vents when the thinning ice cracks. The outrushing gas may carve a spider. Any dust blown aloft settles out downwind as an oriented fan. *ASTRONOMY:* JAY SMITH

the same place. The group also suggests the very presence of a spider ravine may ensure a geyser forms there each year.

Last year, Ganna Portyankina of the Max Planck Institute for Solar System Research in Katlenburg-Lindau, Germany, studied more than 320 MGS spider images. They clearly show that spiders are depressions, as expected from the vent model. She was also able to find one spider probed by the spacecraft's Mars Orbiter Laser Altimeter (MOLA). MOLA gathered more than 600 million elevation measurements before it stopped working in 2001. From these data, scientists constructed a detailed topographic model of the Red Planet's surface. Although the spider MOLA tracked through is too shallow for its depth to be measured, Portyankina showed the spider's surrounding terrain is flat, which is consistent with a thick cover of ice.

Same pole, different climates

But why should the western half of Mars' SPC form snow, while the eastern half forms transparent ice? The answer came in a May 2005 study led by Anthony Colaprete and including Hugh Kieffer and Tim Titus. They found that three of the Red Planet's most impressive topographic features distort Mars' weather so much, they create different climates on either side of the south pole.

The team combined a detailed computer simulation of the Mars atmosphere — called a general circulation model — with MOLA-derived martian topography. The southern tip of the bulging Tharsis region, which contains the planet's largest volcanoes, is one piece of culprit terrain. "The beauty of being a modeler is it allows you to level a mountain and fill in craters with a few lines of code," Colaprete says. When the scientists flattened Tharsis in their topographic model, a zone of cooler temperatures moved about 10-percent closer to the geographic south pole.

But the giant impact basins Hellas and Argyre together produce most of the effect. Hellas, which is almost as wide as the continental United States, is nearly 7 miles (11 km) deep. Argyre is about half Hellas' width and depth, and both of these enormous basins occur at about the same latitude. "Fundamentally, the winds blowing over the ups and downs in the topography set up a wave pattern in the atmosphere," says team member Jeffrey Barnes of Oregon State University.

"These two obstacles have been conveniently positioned to dominate the dynamics of the entire southern hemisphere," Colaprete says. Because southern winds on Mars predominantly blow east to west, as on Earth, the general pattern becomes locked to large dips and rises on the planet's surface. This pattern induces significant north-to-south winds, which slightly warm one hemisphere. Removing the giant basins resulted in a symmetrical zone of cold temperature around the south pole.

"On Mars, topography is so extreme, and the atmosphere is so thin, that the forcing it brings to the atmosphere is very pronounced," Colaprete says. "Ninety percent of the forcing comes from those two basins. They play off each other." Without these features, the Red Planet's permanent southern ice cap would be centered right on its geographic south pole.

Once formed, storm systems tend to stay in place, producing bright, reflective snowfalls on the pole's western side. This forms the visible ice cap as well as extensive seasonal deposits. But on the warmer eastern side, the martian equivalent of black ice wins out. "A big skating rink is the image I have in my mind," Barnes says.

Compelling as the venting-spider scenario may be, an instrument named OMEGA aboard the European Space Agency's Mars Express spacecraft is hinting the cryptic region's slab ice may not always be as clear as Kieffer thinks.

At OMEGA's near-infrared wavelengths, a thick slab of clear CO_2 has a unique and easily identifiable spectral signature. Yves Langevin at the Institut d'Astrophysique Spatiale in Orsay, France, says OMEGA does see this signature at different times and places. More typically, though, OMEGA is finding that the cryptic region's near-surface layers have lots of dust — dust that dims sunlight penetrating the ice and heating the surface. This doesn't mean Kieffer's model won't work, Langevin notes, but, "One must be cautious before claiming that solar heating is the simple answer."

Kieffer agrees. "What we really need here is to put together the images and temperatures to determine the evolution of the features. We'll probably find several classes of spiders," he explains. "I encourage people to have at this."

MGS images show polar features planetary scientists only now are beginning to understand. Earlier ideas of the Red Planet's ice-atmosphere interaction, extended from what we see happening on Earth, were oversimplified. "It's a great example of how planetary scientists must learn to think like martians," Kieffer says. "We're dealing with physics for which there's no terrestrial experience."

ONLINE EXTRA Visit www.astronomy.com/toc to see more strange martian iceforms.

BY MARTIN RATCLIFFE AND ALISTER LING

JULY 06

Although the king of planets rules July evenings, the dazzling predawn spectacle of a crescent Moon passing through the Pleiades star cluster tops this month's list of celestial delights.

Jupiter sails south

Like a distant lighthouse beacon, the glow of Jupiter low in the southern sky after darkness falls surely will catch your eye. Its steady, pale-peach hue stands in stark contrast to sparkling blue-white Spica to its right and twinkling rusty-orange Antares to the left. Many people will notice the bright light because it now lies in our field of view; anything higher in the sky tends to go unnoticed.

You can start observing Jupiter as soon as it becomes visible in evening twilight. The late-day atmosphere typically is well-mixed, which reduces the rippling waves that interfere with clear views. Don't be put off by haze or light pollution — they have little effect on the planets. Patience will be your biggest ally. The more time you spend at the eyepiece gazing intently at Jupiter's cloud tops, the more detail you'll see.

What starts off as two straight bands crossing a uniform disk resolves into multiple lines with ruffled edges, white spots, dark "barges," and wispy festoons, dark features that jut into Jupiter's bright Equatorial Zone. Sometimes, you can catch the Great Red Spot. Its 2-decade-long pallor has made seeing it a challenge compared with the brick-red hue it exhibited at the start of the Space Age.

Earth's North Pole points away from this part of space, so the planets and Moon scoot low across the southern sky these July nights. On the positive side, this makes the Sun climb high and gives us the longer, hotter days of summer. Viewed from the Southern Hemisphere, Jupiter passes nearly overhead — 6 years of great observing has started.

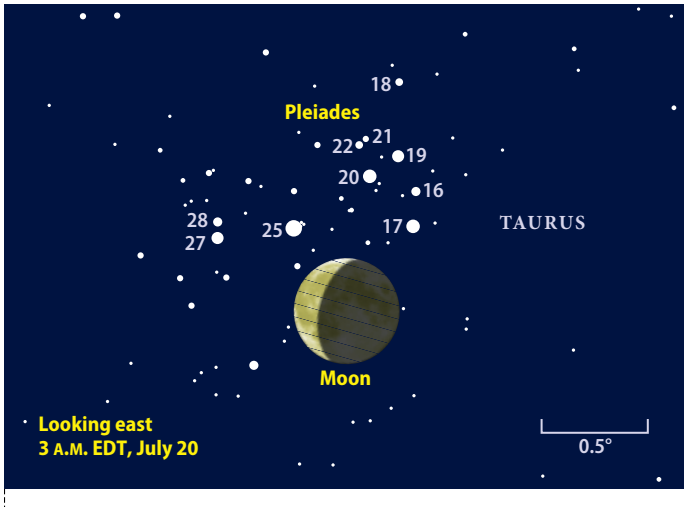
Mars and Saturn remain visible in the west-northwest an hour after sunset in early July, but twilight does a good job of masking them. Binoculars make them easy to spot. The only bright star nearby that might confuse you is Regulus. This star lies to the planets' upper left, and its blue-white color should give it away. Keep an eye on Regulus as it sinks deeper into the twilight during the next few weeks. It skims below Mars July 22, leaving a gap large enough for the Moon to pass through.

When Saturn returns to the evening sky next winter, it will be in close company with Regulus. The planet's rings will look much flatter then, as they approach their edge-on appearance in 2009.

The Moon's orbit carries our satellite much farther from the celestial equator than usual this year, forcing Luna to cut abnormally low across the southern sky during its evening parade. On the night of July 5, it passes south of Jupiter by 5°, nearly a full binocular field of view. The low elevation means the Moon's light has to travel a longer path through our atmosphere. Compared with the stark white Moons of winter, summer Moons are painted with a warmer, pale-yellow hue.

If there's one event worth setting your alarm for, it's a passage of the crescent Moon through the Pleiades star cluster. On the morning of July 20, observers in the eastern half of North America should have a great view. Binoculars will show a spectacular vista, with the Moon's dark face filled with gray earthshine. Through a telescope, you can watch the bright limb snuff out stars in the blink of an eye. Thirty to 60 minutes later, they pop back into view from behind the dark limb.

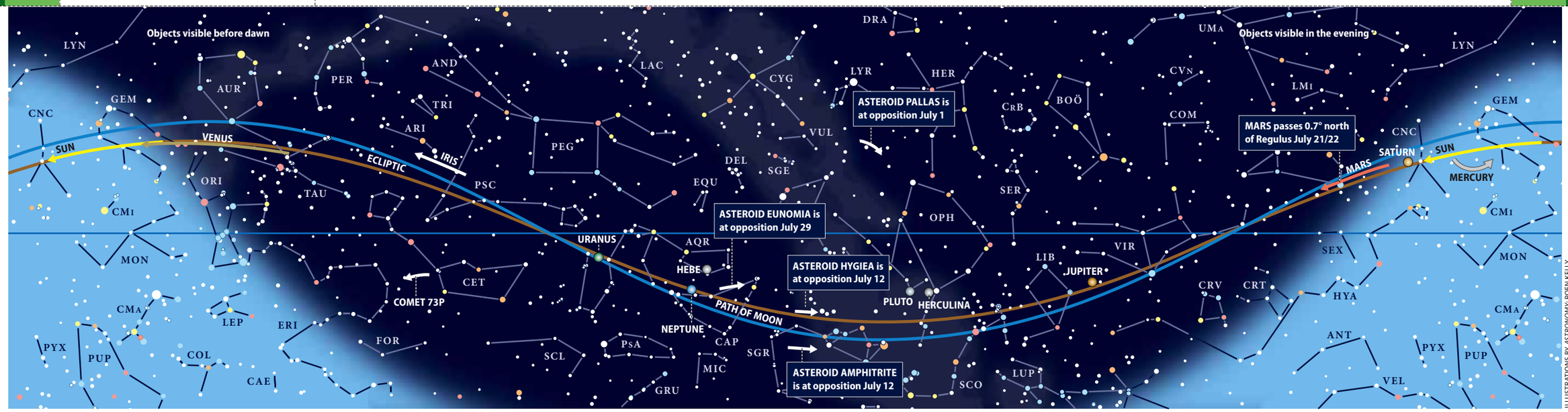
When the Moon returns to the evening sky July 27, it will be a lovely crescent lined up with Mars and Regulus. The Moon actually covers up Mars as seen from Europe, but this event occurs during daylight and won't be impressive.



THE CRESCENT MOON slides through the Pleiades star cluster the morning of July 20. *ASTRONOMY:* ROEN KELLY

Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.



ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

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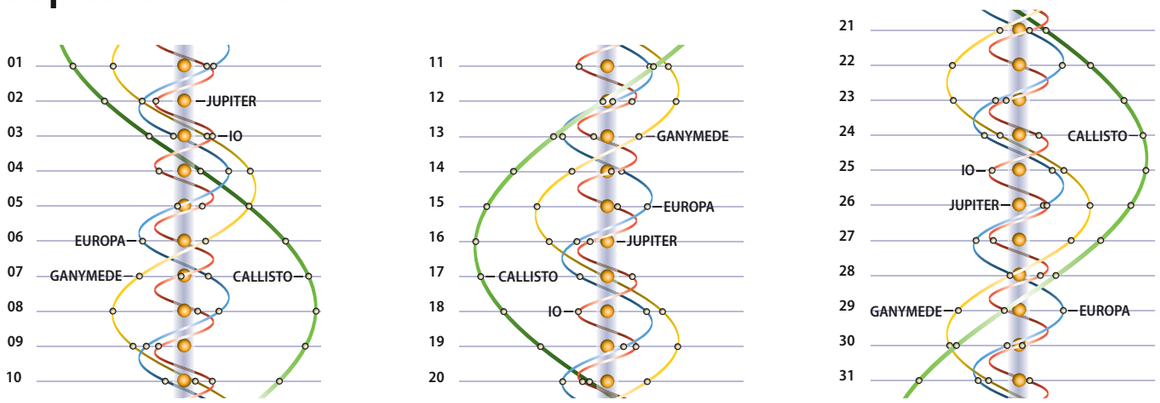
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	July 1	July 31	July 15	July 15	July 15	July 15	July 15	July 15	July 15
Magnitude	—	—	–3.7	1.8	–2.2	0.4	5.8	7.8	13.9
Angular size	10.0"	9.2"	11.5"	3.9"	39.2"	16.5"	3.6"	2.3"	0.1"
Illumination	21%	18%	88%	97%	99%	100%	100%	100%	100%
Distance (AU) from Earth	0.673	0.729	1.455	2.425	5.027	10.094	19.441	29.143	30.245
Distance (AU) from Sun	0.465	0.380	0.723	1.664	5.407	9.142	20.082	30.054	31.141
Right ascension (2000.0)	8h10.4m	7h29.3m	5h38.2m	9h51.0m	14h27.9m	8h57.9m	23h03.7m	21h26.1m	17h37.8m
Declination (2000.0)	18°31'	18°26'	22°27'	14°15'	–13°28'	18°00'	–6°53'	–15°19'	–15°45'

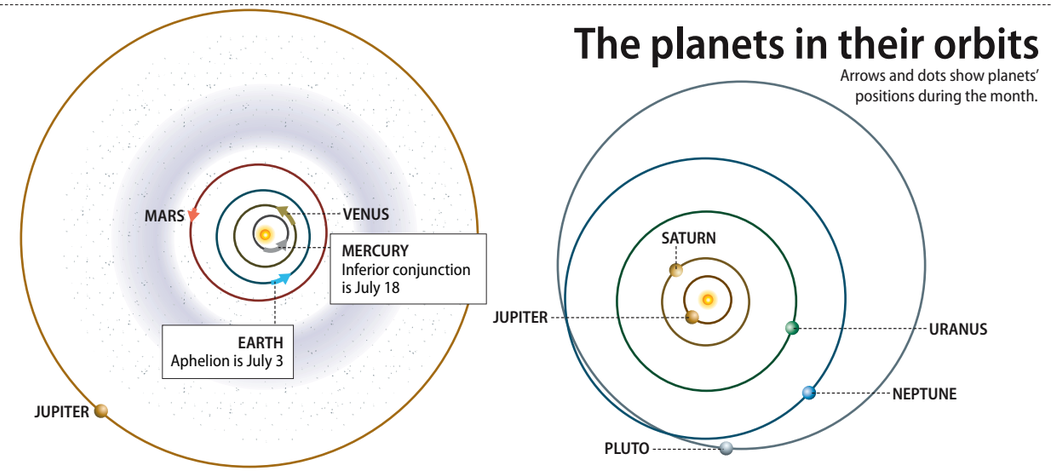
Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on date shown. South is at top to match the view through a telescope.



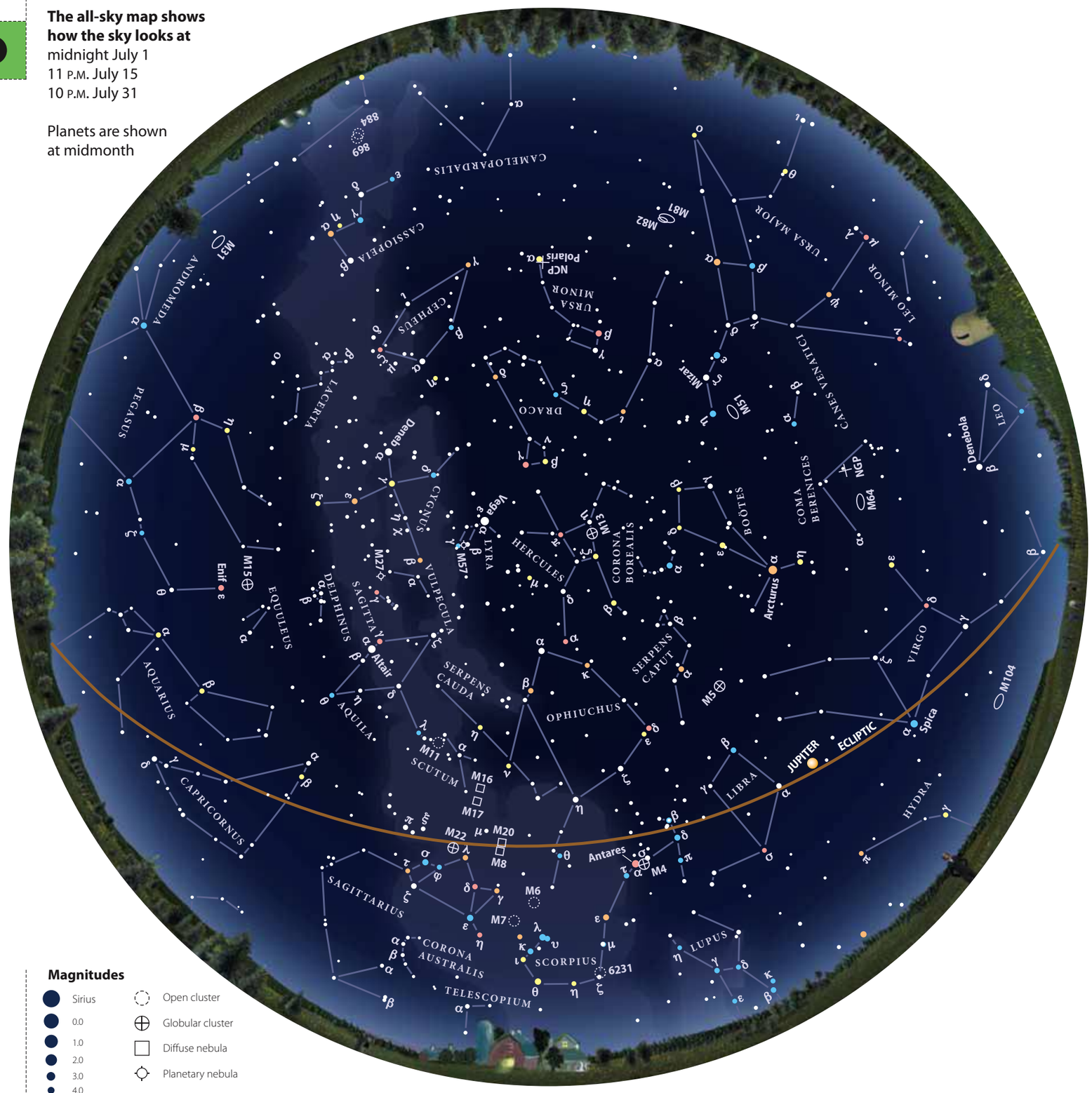
The planets in their orbits

Arrows and dots show planets' positions during the month.



The all-sky map shows how the sky looks at
midnight July 1
11 P.M. July 15
10 P.M. July 31

Planets are shown at midmonth



Magnitudes

Sirius	Open cluster
0.0	Globular cluster
1.0	Diffuse nebula
2.0	Planetary nebula
3.0	Galaxy
4.0	
5.0	

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

july 06

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
						[01]
[02]	[03]	[04]	[05]	[06]	[07]	[08]
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[23]	[24]	[25]	[26]	[27]	[28]	[29]
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ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

01 The Moon is at apogee (251,312 miles from Earth), 4:11 P.M. EDT

02 Venus passes 4° north of Aldebaran, 4 P.M. EDT

03 First Quarter Moon occurs at 12:37 P.M. EDT

Earth is at aphelion (94.5 million miles from the Sun), 7 P.M. EDT

04 The Moon passes 0.1° south of Spica, 1 P.M. EDT

05 The Moon passes 5° south of Jupiter, 10 P.M. EDT

08 The Moon passes 0.2° south of Antares, 4 A.M. EDT

10 Full Moon occurs at 11:02 P.M. EDT

13 The Moon is at perigee (226,358 miles from Earth), 1:33 P.M. EDT

17 Last Quarter Moon occurs at 3:13 P.M. EDT

18 Mercury is in inferior conjunction, 3 A.M. EDT

22 Mars passes 0.7° north of Regulus, 2 A.M. EDT

The Moon passes 6° north of Venus, 8 P.M. EDT

25 New Moon occurs at 12:31 A.M. EDT

27 The Moon passes 1.1° north of Mars, 1 P.M. EDT

28 Southern Delta Aquarid meteor shower peaks

29 The Moon is at apogee (251,908 miles from Earth), 9:02 A.M. EDT

31 The Moon passes 0.4° south of Spica, 9 P.M. EDT

ONLINE EXTRA For definitions of terms, visit www.astronomy.com/glossary.

THE DEEP SKY

When the sky glows brightly from twilight or the scourge of light pollution, visit the star clusters that populate the summer Milky Way.

Clusters for bright nights

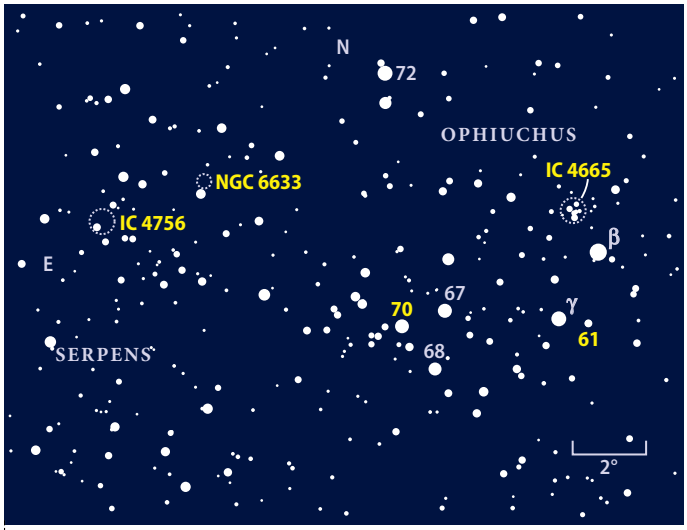
For many backyard observers, summer is not welcomed with open arms — the sky just doesn't get totally dark during the brief night. Latitudes north of 50° suffer from perpetual twilight — the Sun performs a shallow slide under the northern horizon before rising all too soon in the northeast. An equally challenging problem faces big-city dwellers who don't have the means to get to dark sites.

But this is no time to give up. One solution to the bright-sky problem is to observe open star clusters. Individual stars in a cluster pierce through haze and gray skies better than any other class of deep-sky object. Naturally, the clusters cataloged by Charles Messier appear most prominent, but they aren't the only good ones.

Perhaps the easiest non-Messier cluster for northern observers to find is NGC 6910. It lies less than 1° north of Gamma (γ) Cygni, the central star of the Northern Cross. Simply aim your scope at Gamma, and then shift toward Polaris by half a field of view. This splashy group contains two lovely yellow-orange luminaries surrounded by a dash of white followers.

A stunning cluster lurks near the horizon for those at mid-northern latitudes. NGC 6231 in Scorpius lies slightly north of Zeta (ζ) Scorpii. It consists of more than a dozen 6th- and 7th-magnitude white stars crammed together with scores of more modest companions. Even if NGC 6231 skims only a few degrees above your southern horizon, it will impress you.

NGC 6231 packs dozens of stars into an area only one-quarter the size of the Full Moon. TONY AND DAPHNE HALLAS



ASTRONOMY: ROEN KELLY

EASTERN OPHIUCHUS abounds with stunning star clusters perfect for backyard observers with binoculars or small scopes.

A classy trio

Regardless of where you live, the sky near the celestial equator delivers glittering clusters that climb well above the horizon. Three favorites lie along the northern branch of a Milky Way spiral arm in eastern Ophiuchus. Aim your binoculars at Beta (β) Ophiuchi, and you'll see several bright stars topped off by a large, bright cluster.

IC 4665 ranks as the easiest *Index Catalogue* object to view in the northern sky. The prolific visual observers of the 18th and 19th centuries waltzed right over it because their telescopes were too high powered. IC 4665 spans about 2 Moon-widths.

A bit harder to spy from the city is the double gem of NGC 6633 and IC 4756. To find this pair, slide left 2 binocular fields from IC 4665. NGC 6633 appears brighter and more compact than IC 4756, which looks like a detached piece of the Milky Way. Any small telescope will show you the difference between these two star clusters. One appears bright and splashy with plenty of pairs; the other looks like a mound of stardust with added sparkles.

Take a close look at 61 and 70 Ophiuchi through a telescope. The former is an easy double star separated by 21" — half of Jupiter's apparent size. When you factor in its distance of nearly 500 light-years, this translates to a separation of 80 times the distance between the Sun and Pluto. A tighter pair, 70 Ophiuchi is best known for its color controversy. Observers have reported everything from "gold and violet" to "colorless."

THE PLANETS

As Saturn and Mars exit the evening stage, Jupiter dominates the night. The three outer planets put on modest shows around midnight as a prelude to Venus' ascension before dawn.

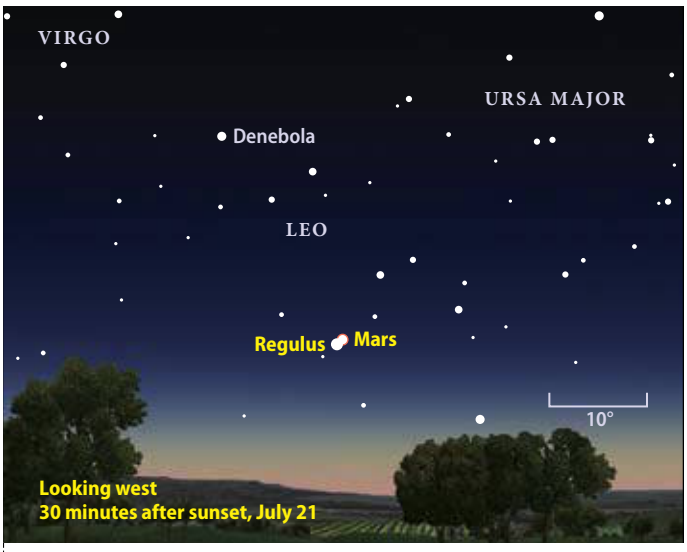
Three planets congregate in the long evening twilight of early July. But you'll have to look fast and have sharp eyes to spot Mercury, Mars, and Saturn.

The brightest of the three is **Saturn**, shining at magnitude 0.4. Spot it low in the west about 40 minutes after sunset. Saturn currently lies in Cancer the Crab, whose dim stars are lost in the twilight. The planet dips below the horizon by 10:30 P.M. local daylight time July 1 and a few minutes earlier each night thereafter. By July's close, it's gone from view, devoured by the Sun's brilliant glow. By August, Earth's motion will carry Saturn to the far side of the Sun.

Mercury briefly shares the same area as Saturn. On July 1, it lies 9° to Saturn's lower right. The innermost planet appears noticeably fainter, however, and fades each consecutive night. You'll find it nearly impossible to pick up in the bright twilight and low-altitude haze after the 1st unless you observe through crystal-clear air and can see down to the horizon. Mercury passes between the Sun and Earth July 18, a configuration known as inferior conjunction. It will reappear in the morning sky in late July.

The third member of our evening planetary trio lies a bit higher than its partners. **Mars** shines at magnitude 1.8, making it about one-quarter as bright as Saturn and roughly the same as the brightest stars of the Big Dipper.

Mars wouldn't be worth a second thought if not for its close conjunction with the bright star Regulus July 21/22.



RUDDY MARS passes within 1° of bluish Regulus July 21 — a great time to view the two objects' contrasting colors. *ASTRONOMY:* ROEN KELLY

NASA/JPL/SSI

IO AND ITS SHADOW stood out on Jupiter's disk when the Cassini spacecraft flew by in December 2000.

From July 1 to 20, Mars crosses the 13° separating it from Regulus. By the 21st, the planet stands a mere 41' to the upper right of Regulus. Binocular and low-power-telescopic views of the pair will reveal a memorable color difference. Mars, with its reddish hue, contrasts beautifully with the blue-white star. One night later, Mars has moved noticeably relative to Regulus and then stands 44' almost directly above the star.

Like Saturn, Mars currently lies on the far side of the Sun from Earth. The Red Planet's tiny globe appears only 4" across, too small to show any features. Mark your calendars for July 27, when the 8-percent-illuminated crescent Moon joins Mars and Regulus low in the western sky. Each object lies less than 4° from its neighbor, creating a scenic highlight for sky photographers.

The subtle charms of the evening twilight sky soon get overshadowed by **Jupiter**'s strong performance. The giant planet dominates as soon as the sky starts to darken. Shining brilliantly at magnitude –2.2, it's the brightest object in the sky apart from the Moon. Look for it low in the southwest as twilight fades. It remains on view until after midnight throughout July. A waxing gibbous Moon passes 5° south of Jupiter July 5.

Jupiter resumes its eastward motion against the background stars this month. Each night, it stands slightly closer to Alpha (α) Librae, also known as Zubenelgenubi, and ends July

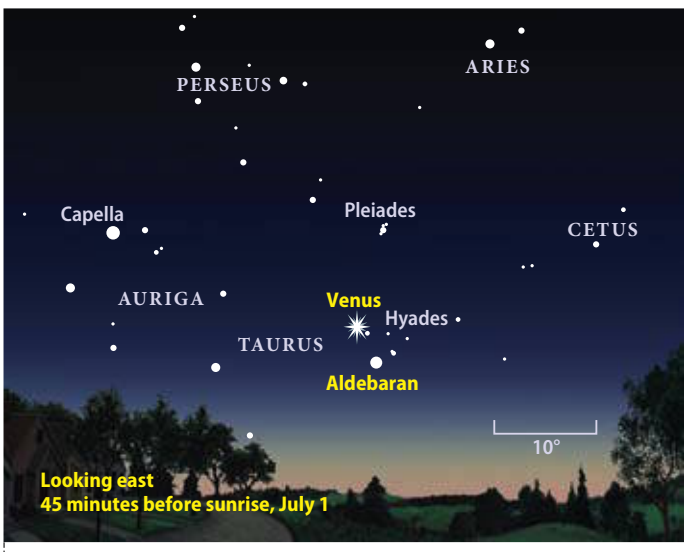
5° shy of this 2.6-magnitude star. Any telescope will deliver a fine view of Jupiter's disk, which spans 39" in mid-July. The alternating dark belts and bright zones in Jupiter's atmosphere change their appearance in subtle ways from night to night. Tracing these changes can be one of the more enjoyable aspects of observing with a small telescope.

Warm evenings also make the giant planet a fine target for casual viewing. Show it off to your friends and neighbors. They may never have seen a planet through a telescope — particularly one as impressive as Jupiter. The sight will let them experience the same thrill of discovery Galileo had 400 years ago, when he saw, for the first time, four tiny moons orbiting the giant planet.

Io, Europa, Ganymede, and Callisto wander back and forth in the plane of Jupiter's equator. Because they revolve in different periods, this produces a fascinating mix of patterns. Io, for example, takes less than 2 days to complete one orbit. You can see its motion over the course of 1 evening. Callisto, the outermost major moon, takes nearly 17 days to finish one orbit and remains roughly in the same position during a single night.

This month offers one of those rare occasions when locating the star field that contains **Pluto** is a snap. The outermost planet continues its motion near the 3.5-magnitude star Xi (ξ) Serpentis. On July 17, Pluto lies 21' due south of Xi. You'll find a 6th-magnitude star exactly 10' south of Xi, so Pluto's location just about doubles this distance. The June *Astronomy* contains a finder chart for Pluto that includes its position throughout July.

Although finding the right field of view is easy, actually seeing Pluto is not. Pluto reached opposition in June and remains at its brightest: magnitude 13.9. Visually sighting an object this faint is a challenge for anyone with a scope smaller than 10 inches in aperture. The planet's visibility depends on many factors, such as local light pollution, the transparency of Earth's atmosphere, and the acuity of your eyes.



VENUS JOINS THE HYADES star cluster at the beginning of July, giving the V-shaped cluster a second bright tip. *ASTRONOMY:* ROEN KELLY

ASTRONOMY: ROEN KELLY

JUPITER'S BRIGHT MOONS occasionally line up on one side of the planet, making them tempting targets through small scopes.

Pluto's neighbor, **Neptune**, remains in Capricornus the Sea Goat this month. Neptune glows dimly at magnitude 7.8, which makes it a good target for binoculars or a small telescope. You can find it 1.8° north-northeast of Iota (ι) Capricorni, where it stays visible all night. On July 10, Neptune appears to be double. This illusion comes about as it passes 2' south of an 8th-magnitude star. Neptune's motion relative to the star will be obvious over 2 consecutive nights.

Uranus is easy to spot in binoculars and, at magnitude 5.8, can be glimpsed with the naked eye under a dark sky. This month, it lies in Aquarius the Water-bearer near the stars 82 and 83 Aquarii (magnitudes 6.2 and 5.4, respectively). Uranus passes between these two July 24 on its way toward 6.2-magnitude 81 Aquarii. Uranus and the stellar trio lie 3° east of Lambda (λ) Aquarii and appear reasonably high in the sky from local midnight through the early morning hours.

Just as Jupiter dominated the evening sky, **Venus** rules the morning. Venus rises 2 hours before the Sun July 1, when it has a spectacular placing just north of Aldebaran. In fact, it forms a second tip to the V-shaped Hyades star cluster. Shining brilliantly at magnitude –3.7, Venus traverses Taurus the Bull until the third week of July. On the 20th, it lies 1.5° south of the open star cluster M35 in the constellation Gemini the Twins. Two mornings later, a slender crescent Moon passes 8° above Venus. A small telescope shows Venus to be pretty bland this month, with an 11"-diameter disk that's about 90-percent illuminated.

By July's close, **Mercury** re-emerges in the morning sky. As it rises out of the brightening morning twilight, it stands 7° directly below Venus. Mercury pales in comparison to Venus, but will grow brighter and more prominent during the first week of August.

Martin Ratcliffe *is the former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist for Environment Canada.*

METEORS AND MOONS

The Moon conveniently exits the morning sky in time to give us a good view of July's premier meteor shower. Earlier in the month, the Moon nicely displays the Apollo 14 landing site.

Meteors galore

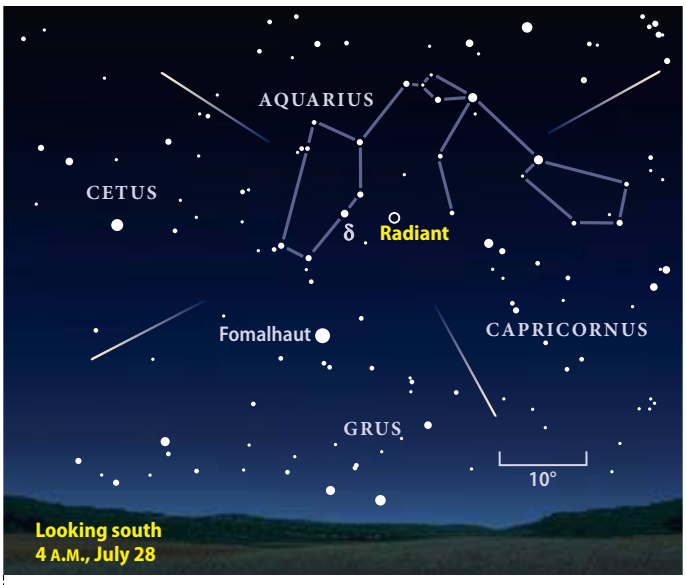
Viewing the southern branch of the Delta Aquarid meteor shower benefits this year from the Moon's absence. This annual shower's activity stretches from July 12 to August 19, so it significantly overlaps next month's Perseid meteor shower. The southern Delta Aquarids should peak July 28, just 3 days after New Moon.

At its peak, this shower produces a zenithal hourly rate — the number of meteors that would be seen per hour under a pitch-black sky if the radiant were overhead — between 15 and 20. From North America and Europe, however, the radiant never climbs this high, so observers typically see about half as many meteors. The radiant reaches its greatest elevation between 3 and 4 A.M. local daylight time.

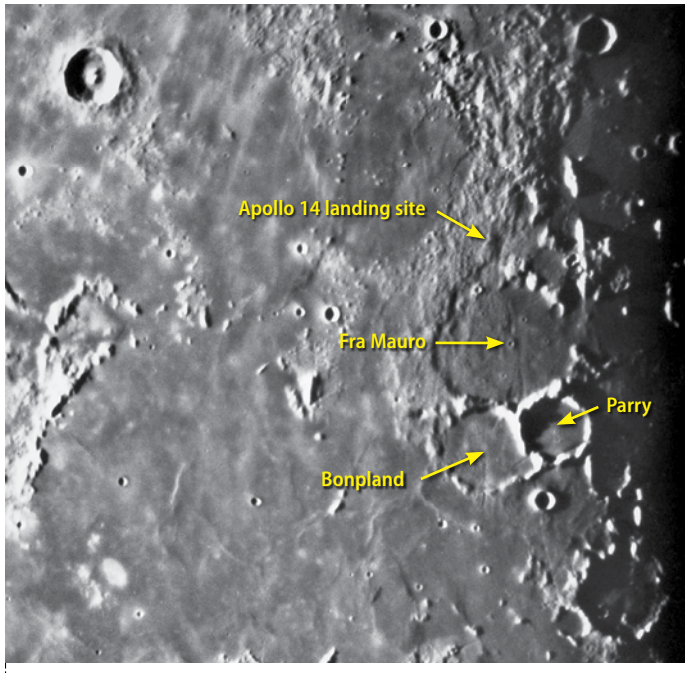
A second stream of Delta Aquarids, the northern branch, also is active in late July and much of August. It peaks at the end of August's first week, so moonlight interferes with it significantly.

Antares on the Moon

On February 5, 1971, the Apollo 14 lunar module — Antares — touched down in the Fra Mauro region. This site was originally the target for the Apollo 13 flight. That mission was aborted after an oxygen tank on the service module blew up. You can see the Fra Mauro region through a backyard telescope, although the Antares lander itself is far too small to glimpse from Earth.



METEORS WILL STREAK across the late-July sky as the southern Delta Aquarid shower reaches its peak. *ASTRONOMY:* ROEN KELLY



FROM *CONSOLIDATED LUNAR ATLAS* (LPL/UA)

APOLLO 14 LANDED just north of the crater Fra Mauro, in a hilly region that contains material from the Mare Imbrium impact.

Named after a 15th-century Italian monk and mapmaker, Fra Mauro Crater lies slightly west and just south of the center of the Moon's disk. Apollo 14 landed just a couple of dozen miles north of the crater's rim. Planetary scientists think this hilly region contains ejecta blasted out from the massive impact that created Mare Imbrium early in the Moon's history. Numerous impacts since the mare's formation have stirred up the surface, burying the original ejecta blanket.

Fra Mauro is an ancient and worn crater that measures about 60 miles across. Its battered walls are almost buried on the western side, and subsequent impacts have completely obliterated part of the eastern wall. You can find Fra Mauro northeast of Mare Cognitum and southeast of Mare Insularum, both of which lie due south of the prominent crater Copernicus.

Two smaller craters, Bonpland and Parry, lie along Fra Mauro's southern rim. The Sun rises over this region July 4. Under low Sun angles, shortly after sunrise, a rille bisecting the larger of these two craters (Bonpland) shows up nicely. A set of aligned hills crisscrosses the region north of Fra Mauro. These hills point in the direction of the Mare Imbrium impact zone.

COMETS AND ASTEROIDS

A decent asteroid nearly always lurks somewhere in the night sky, and July is no exception. But comets are a different story — this month's best will be tough to see unless we get a surprise.

A comet for Sagittarius

To be bright, a comet needs to be close to both the Sun and Earth. Neither condition applies to 71P/Clark. The nearest it gets to the Sun is the orbit of Mars, where the weak sunlight can't liberate much dust from the comet's nucleus. A comet's brightness principally comes from sunlight reflecting off its dust shroud. Carried outward by solar radiation pressure, the dust can form a tail that streams for millions of miles.

A second tail, made of ionized gas, often gives comets their blue-green sheen. The gas comes from the comet's nucleus, where ice turns directly to gas as the Sun heats the surface. Sunlight then ionizes the gas, and the solar wind carries it away from the Sun. But because Comet Clark lies far out, the only thing we'll likely see is a diffuse fuzzball glowing at 11th or 12th magnitude, fainter than any Messier object.

To get a good view of the comet, get away from city skyglow and sidestep the light of the Moon. During the first week of July, wait until midnight for the Moon to set. After the 22nd, the waning crescent Moon will no longer be a problem. The comet tracks through southern Sagittarius this month, near the 4th-magnitude stars Alpha (α) and Beta (β) Sagittarii. If you live north of 50° latitude, you're out of luck — 71P/Clark remains below your southern horizon.

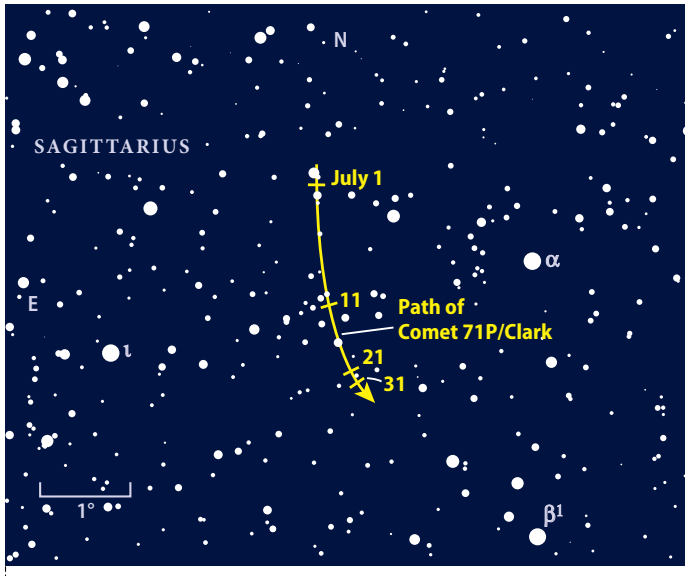
New Zealand astronomer Michael Clark discovered this comet in June 1973. It orbits the Sun once every 5.5 years, which means every second return is lost in the Sun's glare.

Pallas at its prime

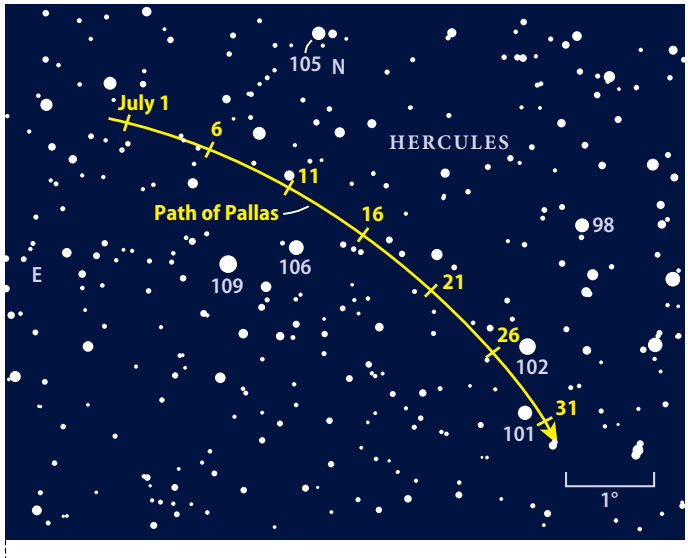
Some kind of accident must have befallen asteroid 2 Pallas during the solar system's early days. As a general rule, the bigger pieces of rocky rubble that orbit the Sun between Mars and Jupiter cling close to the ecliptic, the plane where the planets travel. Pallas' orbit, however, inclines a whopping 35° from its brethren. It likely suffered a big collision long ago that modified a more typical orbit.

German astronomer Heinrich Olbers discovered Pallas in 1802 while looking for the first asteroid, Ceres. Olbers — best known for posing Olbers' paradox: Why is the sky dark at night? — also discovered the brightest asteroid (Vesta) and several comets. Pallas turned out to be a bit more than 300 miles in diameter, making it the second-largest object in the asteroid belt between the orbits of Mars and Jupiter. Its slight motion from one night to the next betrayed its identity.

This same technique will be your best strategy for finding Pallas, which reaches opposition July 1 and remains visible all night. The asteroid takes about 4 days to drift across a typical telescope's low-power field of view. Center your scope on its predicted position in southeastern Hercules, and then make a quick sketch of the six or seven brightest stars. Your sketch will include Pallas, glowing at magnitude 9.5. Come back a night or 2 later to see which dot has moved.



COMET 71P/CLARK should glow around 12th magnitude this month as it slowly moves through southern Sagittarius.



ASTEROID PALLAS reaches opposition July 1, when it glows at magnitude 9.5 among the background stars of Hercules.

Glowing gas and dark dust mingle in spectacular ways among the Swan's star clouds.

/// BY STEVE COE

Explore great nebulae in Cygnus

If you're looking for a constellation with nebulae of all types to observe, then Cygnus the Swan is a great place to start. From mid-northern latitudes, Cygnus climbs high enough to observe from March until November. In March, the constellation appears late at night, and, by November, it sets soon after the Sun. Some people call Cygnus "the constellation that never goes away."

The fuzzy nebulae in Cygnus are clouds of dust and gas that exist between its stars. Several different types of nebulae exist. Let's have a look at them and then highlight Cygnus' collection of these ephemeral beauties.

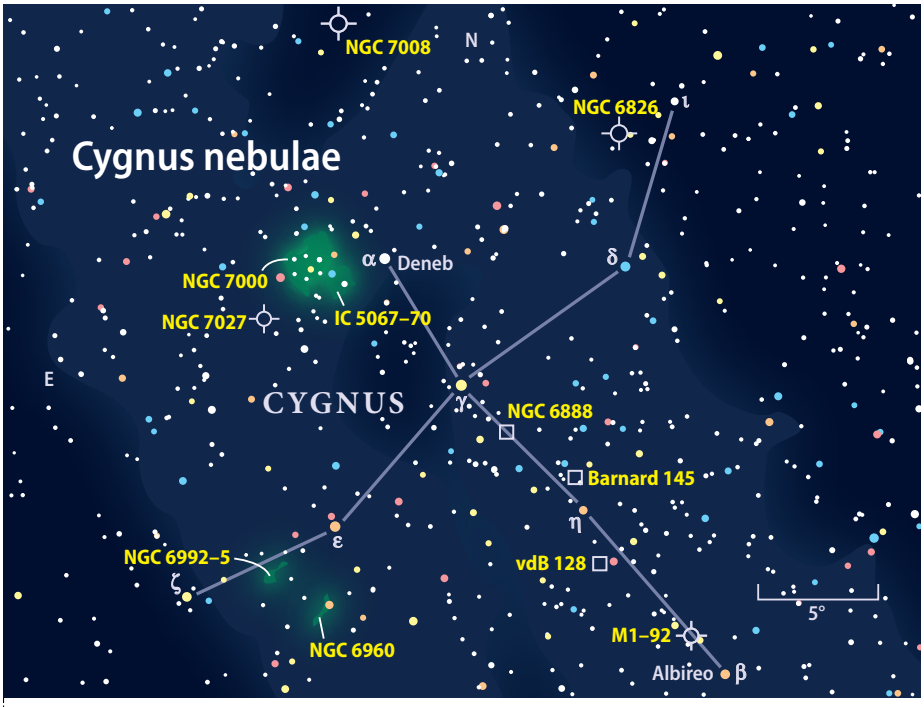
Reflection nebulae do exactly that; they reflect light from a bright star. Reflection nebulae appear blue in astroimages. Arguably the most striking such nebula lies northeast of M45, an open star cluster of hot, blue, young stars in Taurus the Bull known as the Pleiades, or Seven Sisters. NGC 1435 is a faint, diffuse, large reflection nebula located among the stars of the Pleiades that spans about 30', the same width as the Full Moon.

Emission nebulae glow on their own. Powerful ultraviolet (UV) light emitted by bright, hot stars within a nebula excites atoms in the gas. The atoms absorb the UV energy and then re-emit that energy at a longer wavelength, which the human eye can see. The glowing hydrogen, oxygen, and helium atoms give emission nebulae their characteristic red or green color. M42, the Orion Nebula, is the most obvious emission nebula visible to Northern Hemisphere observers.

Dark nebulae are just that — dark. If you've seen the Milky Way where it passes through Cygnus, then you've seen a dark nebula. The Great Rift is a thick, long, dark nebula that passes from the middle of Cygnus along the Milky Way into the constellation Aquila the Eagle. These dark areas are huge clouds of carbon atoms that block starlight from beyond.

Planetary nebulae consist of the glowing gas and dust cast off by medium-size stars like the Sun. Stars with masses similar to the Sun's do not explode at the end of their lives. Instead, they puff off their outer layers until the stars' hot cores are uncovered. These exposed hot cores, called white dwarfs, are hot enough to make the cast-off gas atoms glow. The constellation Lyra offers a spectacular planetary nebulae, the Ring Nebula, or M57. About 2,000 light-years distant, the Ring Nebula has a distinct oval shape and a 14.7-magnitude central star. The nebula spans about 3.5'.

Supernova remnants comprise material blasted away from a massive star at the violent end of its life. One of the most intriguing things about supernova remnants is they will form the next generation of stars,



NEBULAE ABOUND in Cygnus the Swan. The constellation's distinctive crooked-cross shape gives it the appearance of a swan with its wings spread in flight. *ASTRONOMY*: JAY SMITH

▶ THE NORTH AMERICA NEBULA (NGC 7000) is so named because of its shape. This famous emission nebula in Cygnus is 1,600 light-years distant. A dark site and a UHC filter bring out its continental features. ADAM BLOCK/NOAO/AURA/NSF

NGC 6826 is known as the Blinking Planetary because shifting between direct and averted vision makes its central star appear to blink on and off. TOM BOEMER AND DAVID YOUNG/ADAM BLOCK/NOAO/AURA/NSF

planets, and (maybe) astronomers. The IC 443 supernova remnant in Gemini the Twins lies near 3.7-magnitude Eta [η] Geminorum.

From emission nebulae to supernova remnants, the constellation of the Swan is sure to please. Also known as the Northern Cross because of its distinctive shape, Cygnus hosts a variety of eye-catching sights. Now that we're familiar with the nebulae types we can see, let's look at some of Cygnus' lovely gas clouds.

Sight and shape

Planetary nebula NGC 6826 lies 2,200 light-years away, meaning the light you see traveled for 2,200 years before reaching your eye. The nickname of this bright gas cloud is the **Blinking Planetary**. The nebula has a starlike nucleus surrounded by a light-green disk.

Use a 6-inch telescope and 100x magnification to show NGC 6826 as bright, large, and round. Moving up to 150x really shows off its "blinking" effect. When you look directly at the planetary, the central star is prominent compared to the greenish nebulosity. Now switch to averted vision — look away from the nebula toward the edge of the field of view. This will make the nebula appear brighter and overwhelm the star. Alternating between direct and averted vision produces a central star that "blinks."

Moving up in aperture to my 11-inch Schmidt-Cassegrain telescope (SCT) lessens the blinking effect because the central star remains visible all the time. Still, you can use high power to see some nice details within the disk. At 125x, this planetary is bright, large, somewhat elongated, and greenish. The disk floats in a star-rich Milky Way field of view. At 440x, several thin, dark markings appear within the disk that are radial to the central star. Averted vision shows a faint outer region of nebulosity beyond the bright disk on all sides. Using an Oxygen III (OIII) filter — a narrow band-pass filter that allows the doubly-ionized oxygen lines many nebulae emit to pass through while blocking light at other wavelengths — shows off this faint outer glow with more contrast.

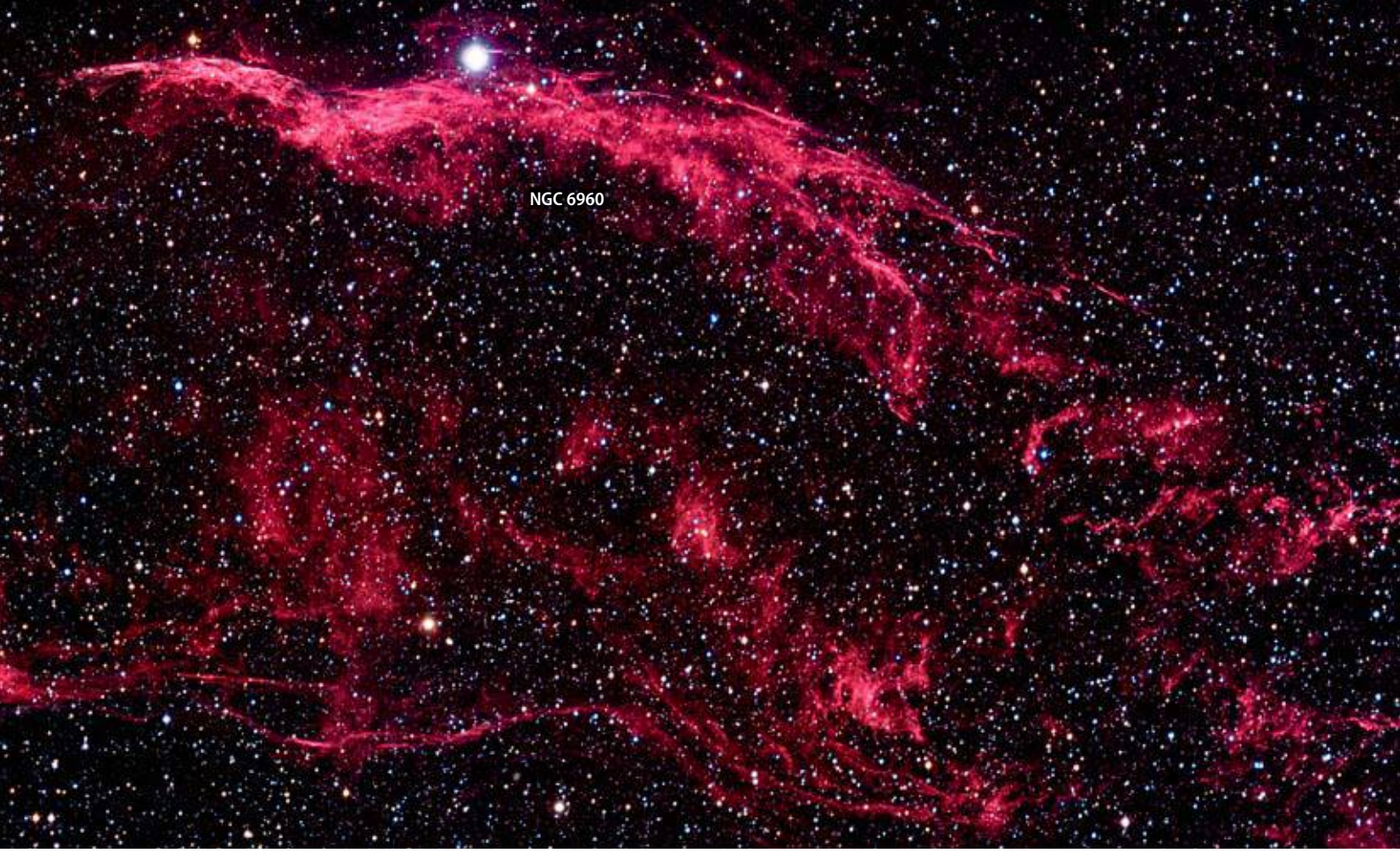
Although the **Crescent Nebula** (NGC 6888) was once thought to be a supernova remnant, modern studies have shown it is a shell of gas and dust pushed away from HD 192163 (V1770 Cygni), a hot, magnitude 7.5 Wolf-Rayet star. These hot stars do not explode like supernovae. Instead, they cast off their outer layers because of the temperature generated when the star's inner layers are exposed.

The Crescent is a difficult nebula to see with a small telescope. With a 6-inch scope on a great night (I rated it 8 out of 10 for transparency), I saw a hint of nebulous glow with a 22mm eyepiece. Inserting a 14mm eyepiece with an Ultra High Contrast (UHC) filter brings out the nebula, but it is faint, large, and has an irregular figure. It appears as an arc of nebulosity with four stars involved and an extremely faint section to the southwest. Turning on a dim red light to write down notes and then returning to the telescope makes the nebula disappear! Pulling a dark piece of cloth over your head allows you to get dark-adapted. This object, which demands the "monk's hood" and a UHC filter on a night rated 8 out of 10, is really faint.

Aperture makes a tremendous difference with the Crescent. Using my 13-inch Newtonian without a filter barely shows NGC 6888. Adding the UHC filter increases the contrast and NGC 6888's detail. The nebula now spans half the field of view, appears fairly bright, and shows the irregular crescent figure and 18 stars involved within the nebula. A nice triple star sits on the south

THE VEIL NEBULA is a collection of nebulae in Cygnus. NGC 6960, top right, is a brighter part of the Veil, which was created about 30,000 years ago by a supernova explosion. NGC 6979, below left, is part of the Cygnus Loop. DANIEL B. PHILLIPS

Steve Coe *has observed the sky from Arizona for the past 30 years. He is the author of* Nebulae, and How to Observe Them *(Springer-Verlag).*

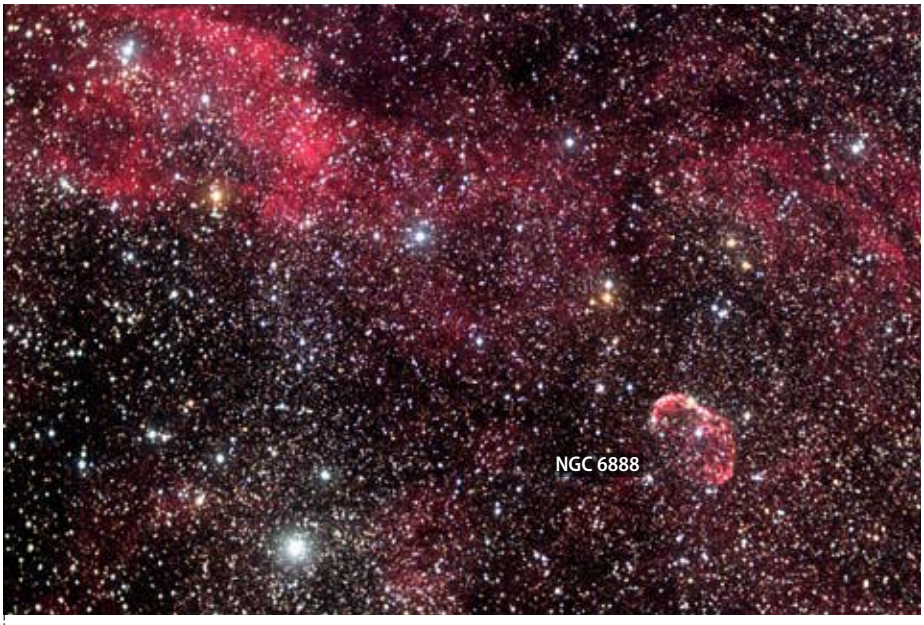


end. The northern part of the nebula is much brighter and forms an arch. It appears the central star has nebulosity attached. Going to 150x with the UHC filter, I can now see the nebulosity doesn't go all the way to the middle star, but the illusion persists when I use averted vision.

Captivating clouds

NGC 6960 and NGC 6992–5 are the brightest parts of the **Veil Nebula**. A supernova created the Veil about 30,000 years ago. NGC 6960 passes behind 52 Cygni, a naked-eye star off the Swan's western wing. This section appears to split into forked branches. NGC 6992–5 lies about 2° from 52 Cygni and glows somewhat brighter than NGC 6960. This nebula is about 1,800 light-years distant, but the star is much closer at 150 light-years, so there is no connection.

Viewing through my 17.5-inch Newtonian reflector with a 20mm eyepiece and a UHC filter, the Veil is amazing. Only about one-quarter of either loop can fit into the field of view, and I must move the scope to scan all that is available. NGC 6992–5 has loops and swirls of nebulosity that give a three-dimensional effect. There are other pieces to the Veil Nebula, most between the two main sections. Much of what can be photographed with an 8-inch Schmidt camera can be viewed by a persistent observer.



NGC 6888, in the lower right of this image, is the result of a hot Wolf-Rayet star casting off its outer layers. Although NGC 6888, also called the Crescent Nebula, is classified as a bright nebula, it appears faint with an irregular figure. ADAM BLOCK/NOAO/AURA/NSF

Use a 6-inch scope and a 22mm eyepiece with a UHC or OIII filter to obtain a great view of the Veil. NGC 6992–5 has a higher surface brightness than NGC 6960. This section (NGC 6992–5) ends in what I call the Dragon Head. This part of the nebula is easy to see, but the twisted taffy-pull structure is only hinted at using the 6-inch scope.

The famous **North America Nebula** (NGC 7000) lies 1,600 light-years away. A dark site and 8x42 binoculars reveal its dim

DARK NEBULA Barnard 145 (top right) in Cygnus is triangular in shape and elongated. The dark nebula sits in a rich star field surrounding Barnard 145. JANNE KÄLD

NGC 7027 is likely a young planetary nebula about 3,000 light-years away. Its beautiful aqua color makes it a must-see object. ADAM BLOCK/NOAO/AURA/NSF

PLANETARY NEBULA NGC 7008 in Cygnus is bright, large, and round with several irregular bright spots. DONN STARKEY, AARON STARKEY/ADAM BLOCK/NOAO/AURA/NSF

glow. Use a rich-field telescope (RFT) — a wide-field, short-focal-length telescope — to see it in its entirety.

With my 4-inch refractor at 20x, the North America shape is easy to see. The dark lanes that frame its shape are obvious. Adding a UHC filter raises the contrast of the "continental" shape. The nearly 3° field of a small scope also shows the fainter **Pelican Nebula** (IC 5067–70) in the same view.

Through a 6-inch scope and a 35mm eyepiece, this nebula is faint, extremely large, and shows many involved stars. The "Mexico" section is the most obvious portion of the nebulosity. An open star cluster (NGC 6997) lies within the "New England" section of the nebula. It appears bright, large, and somewhat compressed with 11 stars resolved in the 6-inch. Going to a 22mm eyepiece resolves 18 cluster stars.

NGC 7008 appears as a bright, large, roundish planetary nebula at 200x in a 17.5-inch. It has several irregular bright spots and three stars involved in the nebula. A nice blue-and-gold double star sits at its edge. This double is John Herschel number 1606, and it is a pair with magnitudes 9.3 and 10.2 separated by 18".

When I observed with a borrowed 25-inch f/5 and a 41mm eyepiece at the Texas Star Party last year, NGC 7008 was bright, large, and rectangular. The central star is seen 20 percent of the time at about 77x. Raising the power to 288x with an 11mm eyepiece provides a great view. Now, the central star shows up 100 percent of the time, and two fainter stars are involved within the nebula. The bipolar aspect of this nebula is obvious with large aperture and high magnification. There are two sections, one much brighter than the other, and the central star sits between the two lobes.

NGC 7027 is a nebula that gets cataloged with planetary nebulae, and evidence seems to support this classification. It lies about 3,000 light-years away. It appears bright and elongated two-to-one at 135x in a 13-inch scope. This beautiful aqua nebula is somewhat rectangular and has a bright spot on the northwest side at 220x.

Barnard 145 is an elongated, triangular dark nebula that sits just west of NGC 6888. Under Arizona Sky Village's dark skies near Portal, Arizona, a 4-inch showed this nebula's triangular shape with little trouble. The nebula fills 40 percent of the field of view at 30x and has many stars involved. Three wide double stars sit nearby. Outside the dark nebula, the field is rich with stars.

M1–92 is the **Footprint Nebula**. It was discovered by Rudolph Minkowski and appeared in a 1946 list of new nebulae, hence its unusual designation. This small, young planetary nebula lies 30" east of a similar-magnitude star, and the pair appears like a double star at low power.

With a 13-inch at 165x, the nebula is bright overall but less bright in the middle. This nebula is elongated two-to-one in position angle 0°. On the night I observed, the star images were about 1" in diameter, and the nebula was about 3". At 250x, both sections — the Footprint's "heel" and "sole" — appear. Neither a UHC nor an OIII filter will make this nebula any easier to see because it reflects light and does not emit its own light.

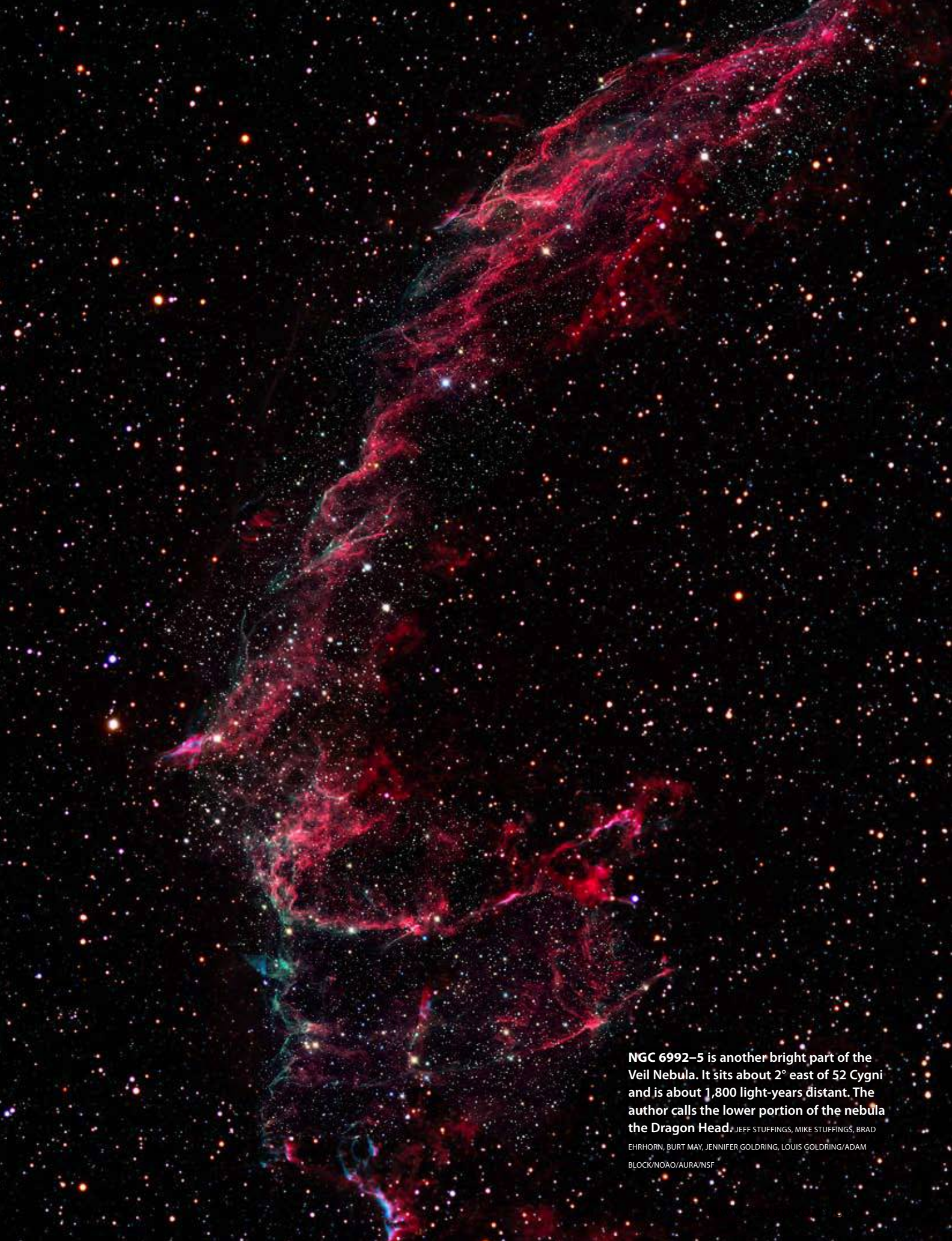
Completing the tour

Let's complete our tour of nebulae in Cygnus with a reflection nebula, **van den Bergh 128**.

Through an 11-inch scope with a 22mm eyepiece, it is faint, large, and irregularly round. This nebula has a yellow star in the middle. A hint of a the nebula's dark lane is easier to spot with averted vision. Adding a UHC filter darkens the background. A deep-sky filter shows the dark lane somewhat better.

While enjoying the sight of a beautiful nebula in my scope, I often think about them being the places where stars and planets are born. I hope you, too, enjoy your nebula hunt in Cygnus the Swan.

ONLINE EXTRA See more Cygnus nebulae at www.astronomy.com/toc.



NGC 6992–5 is another bright part of the Veil Nebula. It sits about 2° east of 52 Cygni and is about 1,800 light-years distant. The author calls the lower portion of the nebula the Dragon Head. JEFF STUFFINGS, MIKE STUFFINGS, BRAD EHRHORN, BURT MAY, JENNIFER GOLDRING, LOUIS GOLDRING/ADAM BLOCK/NOAO/AURA/NSF

DEATH looms

Large, dark clouds can give birth to star clusters, and the constellation Sagittarius features a perfect blend of such light and shadow. There, 4° east of the Milky Way's center, a cluster sprinkled with bright blue stars seems to be emerging from a large black cloud named Barnard 86. The bad news: Even though the cloud may have given birth to the star cluster, the cloud's gravity may also destroy the cluster.

Astronomer **Ken Croswell** *is the author of the new book* Ten Worlds: Everything That Orbits the Sun *(Boyds Mills Press, 2006).*

The emerging cluster, named NGC 6520, is young; otherwise, those short-lived B-type stars would no longer shine. A 2005 study put the cluster's age at 150 million years. That's somewhat older than the Pleiades star cluster (which is about 100 million years old), but only 3 percent of the Sun's age. The dimness of the cluster's stars indicates the cluster is 6,200 light-years distant.

More than a century ago, the black cloud that may have given birth to the cluster caught the eye of American astronomer Edward Emerson Barnard. "For many years I have observed ... a most remarkable small inky black hole in a crowded part of the Milky Way," he wrote in 1890. "It is about 2' in diameter, slightly triangular, with a bright orange star on its [northwestern] border and a beautiful little cluster following. There are other dark holes and vast gaps near this, but nothing so remarkable in the entire circuit of the Milky Way. ... The exceeding beauty of a glass positive from this plate is beyond description."

The black cloud, now named Barnard 86, consists mostly of transparent gas — molecular hydrogen and atomic helium — but 1 percent of its mass is dust grains made

in the DARKNESS

A young star cluster faces an early death from the black cloud that created it. /// BY KEN CROSWELL

THE BLACK CLOUD Barnard 86 (right) may have spawned the young star cluster NGC 6520 (left). This contrasting duo lies roughly 6,200 light-years away, within the constellation Sagittarius. ANGLO-AUSTRALIAN OBSERVATORY/PHOTOGRAPH BY DAVID MALIN

of heavier atoms. The dust blocks the light of the stars beyond and blackens the cloud.

The few stars between us and B86 serve a useful purpose: They allow astronomers to gauge the dark cloud's approximate distance. The farther the cloud, the more intervening stars there should be. Their number suggests the cloud is roughly the same distance as the star cluster. If the two have exactly the same distance, they are 11 light-years apart, and the cloud measures 3.6 light-years across.

Their similar distance from Earth suggests the cloud may well have spawned the cluster. Both the cloud and cluster consist predominantly of hydrogen and helium, but the dark cloud is heavier, weighing about 600 times more than the Sun, whereas the cluster has 300 to 400 solar masses.

Both objects reside far beyond the eight stars that form Sagittarius' teapot shape. Those eight stars shine on the inner edge of the Milky Way's Orion arm — the spiral arm that houses the Sun and Earth — but NGC 6520 and B86 make their home in the next spiral arm inward, the Sagittarius arm.

That's bad news for the cluster, because the inner Milky Way abounds with molecular clouds even larger than B86. The gravity of these clouds yanks stars from clusters.

During the next billion years, NGC 6520 will skirt by so many dark clouds that its stars will spill into the galaxy. No one knows whether the cloud that shadows NGC 6520 gave it birth, but black clouds like B86 will surely cause its death.

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ASK ASTRO

Astronomy's editors and experts from around the globe answer your questions about the cosmos. This month: plasma explained, and what's the difference between asteroids and comets?

PERPLEXING PLASMA

Q: What is plasma, and is plasma in space different from plasma televisions? — WALTER LAREW, FALLS CHURCH, VIRGINIA

A: Scientists use the word *plasma* to name **the state of matter in which most or all of the atoms are ionized**. This fourth state of matter is found in space, in plasma TVs, in lightning, and elsewhere.

An atom becomes ionized when it absorbs enough energy to remove one or more electrons, which leaves a positively charged ion. The atom can acquire the energy necessary for ionization either by colliding with another particle or by absorbing radiation (light). The plasma state is, therefore, a "gas" of charged particles: positively charged ions and the negatively charged electrons that would be bound to the atoms if the system were in the ordinary gaseous state.

Because plasma is made up of charged particles, it can carry electric current and, therefore, produce and respond to electric and magnetic fields. A plasma state is ordinarily maintained only at temperatures greater than about 18,000° F (10,000° C). While the positive ions and the free electrons do recombine, frequent energetic collisions at these extreme temperatures tend to re-ionize any neutral atoms. At lower temperatures, recombination events occur more often than ionization events, so the state of the system is an ordinary neutral gas. High temperatures keep most of the matter in the core and atmosphere of the Sun and stars in the plasma state. Therefore, most of the ordinary (non-dark) matter in the universe is plasma.

Plasmas do not occur only in stars: Some nebulae, the solar wind, and the extended magnetic-field regions (magnetospheres) around planets like Earth and Jupiter are all plasma. The aurora borealis (or northern lights) provides evidence that plasma surrounds Earth. When charged particles from the magnetosphere stream into the upper atmosphere near the poles (where the magnetic field lines dive toward Earth), they collide with neutral gas atoms and cause the gas to emit light.

On Earth's relatively cool surface, plasmas are usually human-made — lightning is one exception. Plasmas are artificially produced by passing an electric current through a low-pressure gas. Fluorescent lighting is the most common example of this.

Plasma TV screens display hundreds of thousands of pixels, and each is essentially a tiny fluorescent lightbulb that produces one of three colors (red, green, or blue). Because the plasmas in fluorescent bulbs (and plasma TV pixels) produce most of their light in the ultraviolet (UV) region of the spectrum, a phosphor coating on the inside of the fluorescent bulb converts the UV light to visible light. The pixels in a plasma TV have special phosphor coatings designed to produce red, green, or blue light.

Plasmas are also used in the production of semiconductor devices (such as computer chips) and in other manufacturing processes. Physicists also experimentally

PLASMA EXISTS in different places, ranging from the Rosette Nebula (A) to the aurora borealis (B). Closer to Earth's surface, plasma is created during the brief moments of lightning flashes (C). It lives longer in experimentally produced plasmas (D). JACK NEWTON; DOMINIC CANTIN; MICHAEL E. BAKICH; PRINCETON PLASMA PHYSICS LABORATORY

study plasmas. They trap and heat plasma with the hope of producing electric power by fusing the nuclei of heavy hydrogen (deuterium and tritium) into helium nuclei — the process that generates energy in the Sun and stars. — **MATTHEW STONEKING,** LAWRENCE UNIVERSITY, APPLETON, WISCONSIN

ROCKY DEFINITION

Q: What is the difference between the nucleus of a comet and an asteroid?

— **ROBYN NAYYAR,** AROMAS, CALIFORNIA

A: A simple, but incomplete, answer is a comet's nucleus actively vents gas from its icy surface, while an asteroid's rocky structure contains no volatile frozen gases, like water, carbon dioxide, and others. In truth, the line between a comet's nucleus and an asteroid is not clearly drawn.

Astronomers think about one in 20 near-Earth asteroids are comets that have lost their ability to outgas — either by exhaustion of their volatiles or by a surface crust that overlays and prevents the interior ices from vaporizing. Four asteroid-like objects that have occasionally exhibited comet-like activity — Chiron, Elst-Pizarro, Echeclus, and Wilson-Harrington — are designated as both an asteroid and a comet.

Images and data from missions to comets Halley, Borrelly, Wild 2, and Tempel 1 suggest cometary nuclei are darker than charcoal; have surfaces no stronger than a weak soufflé; and have very fine silicate dust particles mixed with larger grains consisting of mostly water ice. When the comet approaches close enough to the Sun, the icy material vaporizes, releasing entrained dust particles. This process creates the comet's atmosphere (or coma). The commonly seen dust tail forms when the pressure of sunlight pushes the dust particles away from the Sun. The gas tails form when the ices vaporize. These gases become charged as a result of the Sun's ultraviolet radiation, and they interact with the continuous high-speed stream of charged solar-wind particles.

Current terminology restricts the term *comets* to those icy objects that get close enough to the Sun to induce vaporization. However, any number of outer solar system objects — including Pluto, Kuiper Belt objects, and many icy satellites of Jupiter, Saturn, Uranus, and Neptune — would become comets if they were to venture into the inner solar system and begin vaporizing. Once a comet exhausts its ices, it can either disintegrate into meteor-stream material or become an inert ex-cometary "asteroid." Presumably, these objects would, like their active parent comets, be fragile and porous.

Most asteroids are fragments from asteroid collisions. Some of the large colliding asteroids formed with iron cores surrounded by solid rocky mantles and upper layers of looser rocky material. Upon collision, the resulting fragments can be iron, solid or shattered rock, or collections of looser material.

Stony asteroids are most common in the inner region of the main asteroid belt between the orbits of Mars and Jupiter. Most asteroids in the outer belt region — on the Jupiter side of the belt — are likely mixtures of more fragile clay minerals and carbon compounds. Not surprisingly, some of these farther-out asteroids are dark and have spectral similarities with the surfaces of dark comets.

So, it's probably best to think of comets and asteroids as a continuum of small bodies in the solar system. These bodies range from active, icy comets to wimpy, ex-cometary fluff balls to rubble-pile asteroids of rocky material, and finally, asteroids of shattered rock, solid rock, and even slabs of solid iron. — **DON YEOMANS,** NASA/JET PROPULSION LABORATORY, PASADENA, CALIFORNIA

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

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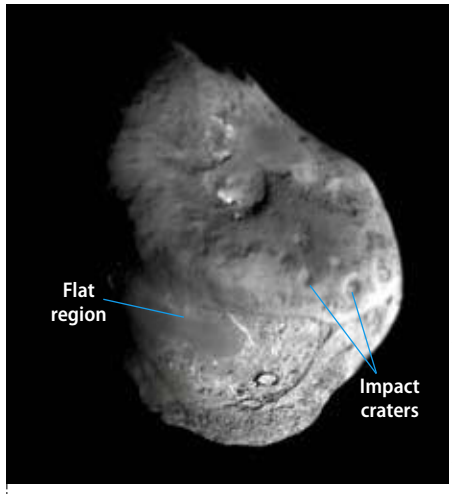
THE ROUGH ROCKY SURFACE of near-Earth asteroid Itokawa is seen here from the Hayabusa spacecraft. The entire asteroid is only about a third of a mile (550 meters) across in its largest dimension.



NASA/JPL/UMD/FRANCIS REDDY

COMET TEMPEL 1 is about 5 miles (8 km) at its widest. The Deep Impact mission's impactor imaged the comet's surface. A relatively young and flat region, and an older region with impact craters, is visible.

IN THE KNOW

RECOMBINATION:
When an ionized atom (an ion) combines with an electron to form a neutral atom; also an epoch in cosmic history that occurred roughly 380,000 years after the Big Bang.

SOLAR WIND:
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VOLATILES:
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Left to right: Astro-Tech AT66ED, $329; AT80, $379; AT80ED, $529

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NP-101, 4" f/5.4 Petzval apo	**3685.00**

No matter whether it's a telecope or an accessory, if it's from TeleVue, chances are good we have it in stock.

A Meade Ritchey-Chrétien for only $2499? *Fantastique!*

Meade 8" f/10 LX200R Ritchey-Chrétien **$2499** *freight paid*

At least we think French optician Henri Chrétien would call it "fantastic" if he were still alive and knew that the kind of telescope optics that he and George Ritchey designed in 1930 – the kind used in the 300" Keck telescopes and the Hubble Space Telescope – were available at prices virtually every backyard astronomer and astrophotographer can afford.

The new **Meade LX200R** telescopes use f/10 versions of the modified Ritchey-Chrétien optics used in Meade's famous RCX400 scopes. They are mounted in the proven mechanics of the best-selling Meade LX200GPS series. The result is genuine state-of-the-art telescopes at prices that are within reach and reason.

The 8" to14" LX200R scopes usually ship from our stock, saving you time over non-stocking dealers who must have Meade ship them to you (and if you live in California, we save you the sales tax).

Here are the *freight-paid* prices on the LX200R scopes that we ship from our stock:

8" **LX200R**	**$2499.00**
8" **LX200R,** with UHTC optics	**2674.00**
10" **LX200R**	**3399.00**
10" **LX200R,** with UHTC optics	**3634.00**
12" **LX200R**	**4399.00**
12" **LX200R,** with UHTC optics	**4694.00**
14" **LX200R**	**5999.00**
14" **LX200R,** with UHTC optics	**6349.00**

Because of their weight, these 16" LX200R scopes ship to you via truck from Meade.

16" **LX200R,** without mount, w/UHTC	**11,529.00**
16" **LX200R,** tripod, w/UHTC	**12,494.00**
16" **LX200R,** altaz pier, w/UHTC	**12,524.00**
16" **LX200R,** eq pier, w/UHTC	**12,779.00**

Outer space is infinite. Your car's back seat is not.

Meade LightBridge Dobsonians use a truss-tube design that lets even the big 12" models break down into a few small packages that easily fit into a compact car. One person can transport even the largest Meade LightBridge to a dark sky site and set it up on their own.

Meade 10" f/5 standard LightBridge **$649**

All Meade LightBridge Dobs have a 2" machined aluminum Crayford-style focuser with a 1.25" eyepiece adapter. A battery-operated fan on the metal primary mirror cell assures fast cooling of the diffraction-limited BK7 optical glass mirror. No tools are needed to assemble and break down the scope in the field.

Standard models have a 1.25" 26mm Super Plössl eyepiece, a red dot finder, and Teflon bearings. Deluxe models have a 2" 26mm 70° field QX eyepiece, an illuminated finder with four different reticle patterns, and roller bearings for smooth hitch-free motion at the touch of a finger.

The prices below include the shipping from the Meade factory.

8" f/6 standard LightBridge	**$469.00**
8" f/6 deluxe LightBridge	**569.00**
10" f/5 standard LightBridge	**649.00**
10" f/5 deluxe LightBridge	**749.00**
12" f/5 standard LightBridge	**949.00**
12" f/5 deluxe LightBridge	**1049.00**

Celestron *SkyAlign* go-to scopes start at a low $279.

You don't need to know the Pleiades from Polaris to find your way around the sky with a **Celestron SLT** go-to scope. With Celestron *SkyAlign* technology, just point your SLT at any three of the 50 brightest lights in the sky (3 stars, or 2 stars and a planet), and the SLT will find the planets and over 4,000 deep space objects for you *automatically.* A few anonymous points of light are all you need to find your way around the skies.

$379

80mm Celestron NexStar 80 SLT

Celestron SLT no-guesswork go-to scopes are available in these sizes:

NexStar 60, 60mm refractor	**$279.00**
NexStar 80, 80mm refractor	**379.00**
NexStar 102, 102mm refractor	**479.00**
NexStar 114, 114mm reflector	**399.00**
NexStar 130, 130mm reflector	**439.00**

Each has *two* eyepieces, red dot finder, motor drives, stainless steel tripod, NexStar computer, software to control the scope from your computer, and more.

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not just as a business. Our sales may have grown over a thousand-fold since that first year, but we're still the same family-owned, family-run, full-line telescope dealer we were in 1979. And we still love astronomy.

21st century Celestron go-to . . . at a 1984 price.

If you fondly remember the original orange-tube Celestron C8 – the scope that made amateur astronomy affordable – the **Celestron NexStar 8i Special Edition** will bring back the good old days . . . at a low price straight out of the 1980s!

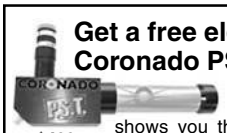
The scope has a modern anodized version of Celestron's vintage orange and black paint, a convenient go-to computer with no-guesswork *SkyAlign* technology, and the bright images of Celestron's best Starbright XLT multicoatings.

The most amazing part? This 21st century telescope is available for less than the price of a C8 from 1984 that didn't even have a computer.

Amateur astronomy has changed a lot over the past 22 years. But a Celestron's value and performance are standards you've been able to rely on – *always!*

Celestron 8" f/10 N8iSE

Get a free electronic eyepiece with the $499 Coronado PST solar telescope.



$499

Coronado's solar scope shows you the constantly changing drama of solar flares and prominences leaping off the Sun. At only $499, it's a world-class value.

The **Coronado PST** (Personal Solar Telescope) doesn't just show you sunspots, like an ordinary solar filter. It shows you the violent face of the living Sun. It includes a 60mm refractor, built-in sub-Ångstrom solar filter, a safe Sun finder, and a 25mm eyepiece.

And now, while quantities last, buy a Coronado PST at its regular price, and you get a Meade electronic eyepiece for free! The $149 list price electronic eyepiece lets you put those fascinating monochrome PST solar images on a TV screen for all to see.

A Meade ED *triplet* apo refractor for only $599? Yes!

The **Meade Series 5000 ED refractor** uses ED (Extra-low Dispersion) glass in its fully multicoated, air-spaced, 80mm *triplet* apochromatic optical system. The ED glass provides extra high contrast, with no false color fringing around bright objects. It makes this refractor superb for wide field CCD and conventional 35mm astrophotography, as well as exceptional for visual observing.

This is an optical tube only, with no mount. It has an adjustable lens cell, Crayford-style focuser, dust covers, L-bracket tripod mount, retractable lens shade, and a hard case.

$699
80mm ED APO package

There is a package version available that adds a $199 retail 2" dielectric star diagonal for only $100.

80mm ED, 3.1" f/6 triplet apo ..... **$599**^{00}

80mm ED, as above, w/2" dielectric diag .... **699**^{00}

> I just wanted to drop a line and tell you how pleased I am with my Celestron C8S-GT (XLT). This was advertised as used, but on unpacking, it appeared as NEW! If this scope was used you can't tell. This is one of the reasons this is my 3rd scope from Astronomics. Keep up the good work!
>
> **Customer Quote of the Month #172**

Celestron NexImage captures the solar system for $99.

The $99 **Celestron NexImage** CCD camera takes high power full color images of the Moon and planets with any telescope. It sends them to your computer to view live or print out later. The full color CCD imaging chip in the NexImage has a big 640 x 480 array of 5.4 micron pixels for sharp and clear high-resolution images.

For wider lunar panoramas, the optional $24.50 NexImage Reducer Lens doubles the camera's field of view.

Celestron Dobs are nifty, inexpensive, *and in stock.*

Celestron StarHopper Dobsonians use roller bearings for smooth hitch-free motion at the touch of a finger.

The 6" StarHopper comes with a 6 x 30mm finder, a 1.25" metal rack and pinion focuser, and a 25mm 1.25" Plössl eyepiece.

8", 10", and 12" StarHoppers have a big 9 x 50mm finder, 2" metal rack and pinion focuser (with a 1.25" eyepiece adapter), and a 32mm E-Lux 2" eyepiece. The 10" and 12" scopes have a battery-operated fan for cooling their primary mirrors. All scopes have fast cool-down metal tubes and BK7 optical glass mirrors, and all are in stock for immediate shipment.

8" f/6 StarHopper
$349

Here are the prices for the fully-equipped Celestron StarHopper Dobsonians we stock.

6" f/8 StarHopper ..... **$249**^{00} + $59 freight

8" f/6 StarHopper ..... **339**^{00} + $69 freight

10" f/5 StarHopper ..... **499**^{00} + $79 freight

12" f/5 StarHopper ..... **849**^{00} + $129 freight

12 volt power to the people for only $59.95!

You can recharge a **Celestron Power Tank** battery many times, saving you the cost of buying flashlight batteries every few weeks to power your scope. 7 amp hour Power Tanks start at only **$59.95**.

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Celestron's SkyScout *tells* you about the sky while it shows you the night's sights.

$399
freight paid

The **Celestron SkyScout** is an award-winning handheld non-magnifying GPS-based personal planetarium that identifies or locates more than 6,000 celestial objects visible to the unaided eye, then tells you their facts and history. Use the SkyScout by itself to learn the legends, myths, and sights of the sky. Or mount it on your telescope to let it guide you from one celestial showpiece to another.

There's a scrolling 5-line display of text and graphics. Supplied earphones let you hear the commentary so you don't have to look away from the sky to read it. Optional speakers let others hear, too.

The SkyScout transforms the night sky into a planetarium for stargazers, families, and students. It makes learning the stories of the sky – *and finding your way around the sky* – easier than ever before.

No-guesswork Celestron *GPS* Schmidt-Cassegrains.

Celestron 8" f/10 CPC800
$1899

It's easy to find your way around the sky with a **Celestron CPC**. Just point it at any three of the 50 brightest lights in the sky (3 stars, or 2 stars and a planet or the Moon), and the CPC will find over 45,000 deep space objects for you at the touch of a button.

You don't have to memorize a star chart to use a CPC. The scope's GPS system and a few anonymous lights in the sky are all you need.

Celestron CPC Schmidt-Cassegrains are fully equipped with all the features you need to start observing immediately.

8" **CPC800**, Starbright multicoatings ... **$1899**^{00}

8" **CPC800X**, XLT multicoatings ..... **1999**^{00}

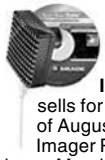
9¼" **CPC925**, Starbright multicoatings .. **2349**^{00}

9¼" **CPC925X**, XLT multicoatings ..... **2499**^{00}

11" **CPC1100**, Starbright multicoatings . **2599**^{00}

11" **CPC1100X**, XLT multicoatings ..... **2799**^{00}

Get a $399 Deep Sky Imager Pro CCD camera for $129 when you buy a Meade telescope.



The **Meade Deep Sky Imager Pro** CCD camera sells for $399. But through the end of August, you can get a Deep Sky Imager Pro for only $129 when you buy a Meade LXD75, LX90, LX200, or RCX400 telescope!

The monochrome Deep Sky Imager Pro is loaded with features, like NASA-developed "Drizzle" software that lets you take unblurred deep space photos with an LX90, LX200, or RCX400 without needing an equatorial wedge. Add an optional color filter set to the DSI Pro to take handsome tri-color images.

The DSI Pro opens up a whole new way to observe with a Meade telescope. Best of all, you save $270 on the DSI Pro when you buy it now with an LXD75, LX90, LX200, or RCX400.

A Telegizmos protects your scope day and night.

A **Telegizmos** scope cover protects your telescope from sun and dew. NASA-developed to insulate spacecraft, these aluminized covers are strong, light, and more durable than Mylar. Prices start at only $29.

Not much cash buys you a lot of Konus.

The low prices of these **Konus** telescopes are downright amazing.

Consider the optically very nice 90mm **Konusmotor-90** f/11 refractor to the left. It has a good-quality equatorial mount, a battery-powered motor drive so you can use it anywhere, and *two* 1.25" Plössl eyepieces. We sell this scope by the dozens, because it's a great value at only $209!

$209
3.5" f/11 Konus refractor

The **Konusky-200** tripod, *dual-axis* DC motor drives, an 8 x 50mm finderscope, polar axis finder, and *two* 1.25" Plössl eyepieces. This 8" Konus is a big telescope for the little price of only $499!

$499
8" f/5 Konus reflector

The **Motormax-150** 6" Maksutov, to the right, has the same heavy duty mount and accessories as the 8" reflector.

6" f/12 Konus Maksutov
$799

This 6" Mak is a terrific value at its low price of only $799, which is well below the cost of other large Maksutovs.

8" f/5 reflector, above right, has a heavy duty equatorial mount with a steel leg

Vixen Sphinx go-to is easy as point-and-click.

The Star Book hand control of the Vixen Sphinx mount makes go-to astronomy easy. Simply move a cursor to an object on the Star Book's 4096-color LCD star chart screen, click on it, and the Sphinx moves to that object. That's it. That's all it takes to find your way around the sky.

As a Vixen stocking dealer, we keep the Sphinx mount in stock for use with your optics or with the premium Vixen optics we stock. It will handle optical tubes from an 80mm refractor up to an 8" reflector or catadioptric scope.

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From south of the equator, you can observe 152 Bennett objects as impressive as the best in the north.

/// BY MICHAEL E. BAKICH

A southern-sky Messier catalog

Professional and amateur astronomers

know South African amateur astronomer John Caister (Jack) Bennett (1914–1990) best for his discovery of Comet C/1969 Y1 (Bennett). But Bennett — in the style of French comet-hunter Charles Messier (1730–1817) — also compiled a list of southern-sky objects he thought present-day novices using small telescopes might mistake for comets.

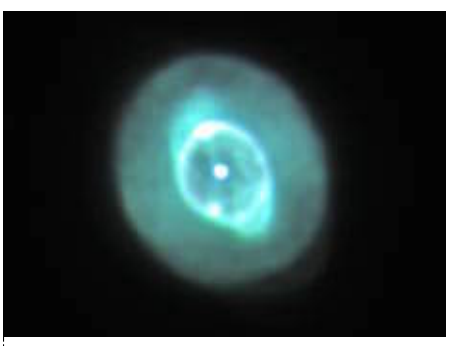
Because of his experience, Bennett knew comet-hunting takes time, patience, and luck. He said, "Searching for comets has been likened to hunting for a needle in a haystack. In actual fact, it is for the most part like looking in a succession of haystacks for a needle that isn't there!"

With the difficulty of comet-hunting in mind, in July 1969, Bennett delivered the presidential address to the Astronomical Society of South Africa. He entitled it *Comet-Hunting in Southern Skies*.

He presented statistics that showed most comet discoveries had been made by northern observers and gave some tips and encouragement for comet-hunters. Bennett introduced a catalog, "As an aid to the recognition of comet-like objects in the southern sky, and to help observers to eliminate them in comet searches, I have over the past 5 years compiled a list of 130 such objects visible south of the celestial equator. Nearly a hundred of these have been encountered under varying conditions in comet sweeps using a 5-inch short-focus refractor with a magnification of 21 diameters. The rest have been added, and duly observed with the same telescope, after consulting various sources."

Bennett listed no brightnesses for his objects. He said, "Magnitudes have not been given. The information available from various catalogs and handbooks is scanty, and in some cases the published figures differ by as much as three magnitudes."

We've come a long way since 1969. Magnitude measurements of extended deep-sky objects, including those in the Bennett Catalog, are now accurate to about a tenth of a magnitude. Because of this, the Bennett



BENNETT 45 (the Ghost of Jupiter) sits less than 2° south of magnitude 3.8 Mu (μ) Hydrae. Also known as NGC 3242, this planetary nebula glows at magnitude 7.7 and consists of a small inner nebula, which measures 16" by 26", surrounded by a fainter envelope about 40" across (about the size of Jupiter), and a faint halo more than 20' in diameter. ADAM BLOCK/NOAO/AURA/NSF

BENNETT 35 (the Tarantula Nebula) in Dorado resides within the Large Magellanic Cloud (LMC). Also known as the Great Looped Nebula and NGC 2070, the Tarantula lies approximately 170,000 light-years away. When the LMC lies near the horizon or when bright moonlight floods the sky, the Tarantula Nebula appears comet-like through a small telescope. DANIEL VERSCHATSE

Michael E. Bakich *is a senior editor of* Astronomy.

THE BENNETT CATALOG

Bennett number	Other name	Type	Con.	R.A. (2000.0)	Dec. (2000.0)	Mag.
1	NGC 55	Gal	Sculptor	0h15m	–39°11'	7.8
2	NGC 104	GC	Tucana	0h24m	–72°05'	4.0
3	NGC 247	Gal	Cetus	0h47m	–20°46'	8.9
4	NGC 253	Gal	Sculptor	0h48m	–25°17'	7.3
5	NGC 288	GC	Sculptor	0h53m	–26°35'	8.1
6	NGC 300	Gal	Sculptor	0h55m	–37°4'	8.1
7	NGC 362	GC	Tucana	1h03m	–70°5'	6.8
8	NGC 613	Gal	Sculptor	1h34m	–29°2'	9.9
9	M77	Gal	Cetus	2h43m	–0°01'	8.9
10	NGC 1097	Gal	Fornax	2h46m	–30°17'	9.5
10a	NGC 1232	Gal	Eridanus	3h10m	–20°35'	9.8
11	NGC 1261	GC	Horologium	3h12m	–55°13'	8.3
12	NGC 1291	Gal	Eridanus	3h17m	–41°08'	8.5
13	NGC 1313	Gal	Reticulum	3h18m	–66°30'	9.1
14	NGC 1316	Gal	Fornax	3h23m	–37°12'	8.9
14a	NGC 1350	Gal	Fornax	3h31m	–33°38'	10.4
15	NGC 1360	PN	Fornax	3h33m	–25°51'	9.4
16	NGC 1365	Gal	Fornax	3h34m	–36°08'	9.5
17	NGC 1380	Gal	Fornax	3h37m	–34°59'	9.9
18	NGC 1387	Gal	Fornax	3h37m	–35°31'	10.8
19	NGC 1399	Gal	Fornax	3h39m	–35°27'	9.4
19a	NGC 1398	Gal	Fornax	3h39m	–26°20'	9.8
20	NGC 1404	Gal	Eridanus	3h39m	–35°35'	10.0
21	NGC 1433	Gal	Horologium	3h42m	–47°13'	9.8
21a	NGC 1512	Gal	Horologium	4h04m	–43°21'	10.2
22	NGC 1535	PN	Eridanus	4h14m	–12°44'	9.6
23	NGC 1549	Gal	Dorado	4h16m	–55°36'	9.6
24	NGC 1553	Gal	Dorado	4h16m	–55°47'	9.0
25	NGC 1566	Gal	Dorado	4h20m	–54°56'	9.4
25a	NGC 1617	Gal	Dorado	4h32m	–54°36'	10.5
26	NGC 1672	Gal	Dorado	4h46m	–59°15'	9.7
27	NGC 1763	N	Dorado	4h57m	–66°24'	—
28	NGC 1783	GC	Dorado	4h59m	–66°00'	11.0
29	NGC 1792	Gal	Columba	5h05m	–37°59'	10.0
30	NGC 1818	OC	Dorado	5h04m	–66°24'	9.7
31	NGC 1808	Gal	Columba	5h08m	–37°31'	9.9
32	NGC 1851	GC	Columba	5h14m	–40°03'	7.1
33	NGC 1866	OC	Dorado	5h14m	–65°28'	9.7
34	M79	GC	Lepus	5h25m	–24°33'	7.7
35	NGC 2070	N	Dorado	5h39m	–69°05'	—
36	NGC 2214	OC	Dorado	6h13m	–68°16'	10.9
36a	NGC 2243	OC	Canis Major	6h30m	–31°17'	9.4
37	NGC 2298	GC	Puppis	6h49m	–36°00'	9.3
37a	NGC 2467	N	Puppis	7h53m	–26°23'	—
38	NGC 2489	OC	Puppis	7h56m	–30°04'	7.9
39	NGC 2506	OC	Monoceros	8h12m	–10°47'	7.6
40	NGC 2627	OC	Pyxis	8h37m	–29°57'	8.4
40a	NGC 2671	OC	Vela	8h46m	–41°53'	11.6
41	NGC 2808	GC	Carina	9h12m	–64°52'	6.2
41a	NGC 2972	OC	Vela	9h40m	–50°20'	9.9

Continued on page 79

Key: Type = Type of object; Con. = Constellation; R.A. = Right ascension; Dec. = Declination; Mag. = Magnitude; GC = Globular cluster; Gal = Galaxy; OC = Open cluster; N = Bright nebula; PN = Planetary nebula

DANIEL VERSCHATSE

BENNETT 6 (NGC 300) in Sculptor shines at magnitude 8.1. NGC 300 measures 19' by 13' and lies only 6.5 million light-years away in the Sculptor group of galaxies. This spiral galaxy contains active star-forming regions, visible in the image as reddish clumps in its arms.

DANIEL VERSCHATSE

BENNETT 43 (the Eight-Burst Nebula), also known as NGC 3132 and the Southern Ring Nebula, is a magnitude 9.2 planetary nebula that sits within Vela the Sails. NGC 3132 glows due to a faint star near its center, not the relatively bright star shown in this image.

DANIEL VERSCHATSE

BENNETT 16 (NGC 1365) in Fornax is the finest barred spiral galaxy in the southern sky. It measures 11' by 6' and shines at magnitude 9.5. NGC 1365 is the brightest member of the Fornax group of galaxies, which lies approximately 60 million light-years away.

Catalog listed here gives the visual magnitude for each object.

As to why he included standout objects like magnitude 3.9 Bennett 61 (globular cluster Omega Centauri) and magnitude 4 Bennett 2 (globular cluster 47 Tucanae) in his catalog, Bennett said, "A few very bright objects have been included, perhaps unnecessarily, but it is surprising how easily even these can be mistaken for comets when seen at low altitudes and under poor conditions. (The same applies to some galactic [open] clusters, which are normally easily resolved into stars.) It is remarkable that when the rest of the Large Magellanic Cloud is quite invisible in the early dawn or in moonlight the Great Looped Nebula [NGC 2070], intensely bright, shines out like the head of a great comet complete with a slightly displaced stellar nucleus."

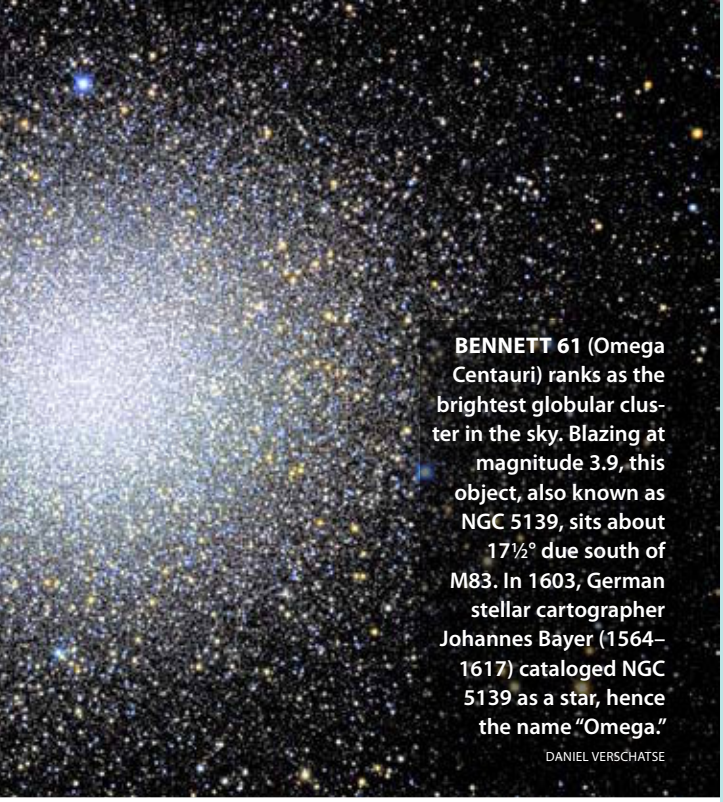
A time of discovery

Amazingly, only 5 months after presenting his talk, Bennett discovered one of the 20th century's brightest comets. He found Comet C/1969 Y1, now known as Comet Bennett, December 28. Using a 5-inch Apogee refractor, he located the magnitude 8.5 object within the constellation Tucana. The search time he invested in his first comet discovery totaled 333 hours.

Comet Bennett reached perihelion (its closest point to the Sun) March 20, 1970, and, 6 days later, it lay at perigee (its closest point to Earth). At its brightest, the comet blazed at 0 magnitude and sported a tail more than 15° long.

C/1969 Y1 wasn't Bennett's first major discovery. On July 16, 1968, he found supernova 1968L in the spiral galaxy M83 in Hydra. In so doing, he became the first person to discover a supernova visually since the invention of the telescope.

In July 1974, Bennett published a list following up his original list of 130 items. His article, "Some Objects of Interest in the Southern Sky," added 22 targets, bringing the total to 152.



BENNETT 61 (Omega Centauri) ranks as the brightest globular cluster in the sky. Blazing at magnitude 3.9, this object, also known as NGC 5139, sits about 17½° due south of M83. In 1603, German stellar cartographer Johannes Bayer (1564–1617) cataloged NGC 5139 as a star, hence the name "Omega." DANIEL VERSCHATSE

BENNETT 63 (M83), a magnitude 7.5 spiral galaxy in Hydra, ranks as one of the sky's brightest galaxies. Slightly elongated (it measures 13' by 11.5'), M83 presents a fabulous target for observers with 8-inch or larger telescopes. Because of its well-defined spiral arms and face-on aspect, which resemble the Pinwheel Galaxy (M33), M83 is known as the Southern Pinwheel. ALLAN COOK/ADAM BLOCK/NOAO/AURA/NSF

THE BENNETT CATALOG *Continued from page 77*

Bennett number	Other name	Type	Con.	R.A. (2000.0)	Dec. (2000.0)	Mag.
41b	NGC 2997	Gal	Antlia	9h46m	–31°11'	9.4
42	NGC 3115	Gal	Sextans	10h05m	–7°43'	9.1
43	NGC 3132	PN	Vela	10h07m	–40°26'	9.2
44	NGC 3201	GC	Vela	10h18m	–46°25'	6.9
45	NGC 3242	PN	Hydra	10h25m	–18°38'	7.7
46	NGC 3621	Gal	Hydra	11h18m	–32°49'	9.4
47	Mel 105	OC	Carina	11h20m	–63°30'	8.5
48	NGC 3960	OC	Centaurus	11h51m	–55°41'	8.3
49	NGC 3923	Gal	Hydra	11h51m	–28°48'	9.6
50	NGC 4372	GC	Musca	12h26m	–72°40'	7.2
51	M68	GC	Hydra	12h40m	–26°45'	7.3
52	M104	Gal	Virgo	12h40m	–11°37'	8.3
53	NGC 4697	Gal	Virgo	12h49m	–5°48'	9.2
54	NGC 4699	Gal	Virgo	12h49m	–8°40'	9.6
55	NGC 4753	Gal	Virgo	12h52m	–1°12'	9.9
56	NGC 4833	GC	Musca	12h59m	–70°53'	8.4
57	NGC 4945	Gal	Centaurus	13h05m	–49°28'	8.6
58	NGC 4976	Gal	Centaurus	13h09m	–49°30'	10.1
59	NGC 5061	Gal	Hydra	13h18m	–26°50'	10.3
59a	NGC 5068	Gal	Virgo	13h19m	–21°02'	9.8
60	NGC 5128	Gal	Centaurus	13h26m	–43°01'	6.6
61	NGC 5139	GC	Centaurus	13h27m	–47°29'	3.9
62	NGC 5189	PN	Musca	13h33m	–65°59'	9.9
63	M83	Gal	Hydra	13h37m	–29°52'	7.5
63a	NGC 5253	Gal	Centaurus	13h40m	–31°39'	10.1
64	NGC 5286	GC	Centaurus	13h46m	–51°22'	7.4
65	NGC 5617	OC	Centaurus	14h30m	–60°43'	6.3
66	NGC 5634	GC	Virgo	14h30m	–5°59'	9.5
67	NGC 5824	GC	Lupus	15h04m	–33°04'	9.1
68	NGC 5897	GC	Libra	15h17m	–21°01'	8.4
69	NGC 5927	GC	Lupus	15h28m	–50°40'	8.0
70	NGC 5986	GC	Lupus	15h46m	–37°47'	7.6
71	NGC 5999	OC	Norma	15h52m	–56°28'	9.0
72	NGC 6005	OC	Norma	15h56m	–57°26'	10.7
72a	Trumpler 23	OC	Norma	16h02m	–53°32'	11.2
73	NGC 6093	GC	Scorpius	16h17m	–22°59'	7.3
74	NGC 6101	GC	Apus	16h26m	–72°12'	9.2
75	M4	GC	Scorpius	16h24m	–26°32'	5.4
76	NGC 6134	OC	Norma	16h28m	–49°09'	7.2
77	NGC 6144	GC	Scorpius	16h27m	–26°02'	9.0
78	NGC 6139	GC	Scorpius	16h28m	–38°51'	9.1
79	M107	GC	Ophiuchus	16h33m	–13°03'	7.8
79a	NGC 6167	OC	Norma	16h34m	–49°36'	6.7
79b	NGC 6192	OC	Scorpius	16h40m	–43°22'	8.5
80	M12	GC	Ophiuchus	16h47m	–1°57'	6.1
81	NGC 6216	OC	Scorpius	16h49m	–44°44'	10.1
82	NGC 6235	GC	Ophiuchus	16h53m	–22°11'	8.9
83	M10	GC	Ophiuchus	16h57m	–4°06'	6.6
84	NGC 6253	OC	Ara	16h59m	–52°43'	10.2
85	M62	GC	Ophiuchus	17h01m	–30°07'	6.4

Continued on page 81

Key: Type = Type of object; Con. = Constellation; R.A. = Right ascension; Dec. = Declination; Mag. = Magnitude; GC = Globular cluster; Gal = Galaxy; OC = Open cluster; N = Bright nebula; PN = Planetary nebula

ADAM BLOCK/NOAO/AURA/NSF

BENNETT 129 (the Helix Nebula) in Aquarius is one of the closest planetary nebulae, lying approximately 450 light-years away. Also known as NGC 7293, this object shines at magnitude 7.3 and measures about 17' across, more than half the size of the Full Moon.

MICHAEL GARIEPY/ADAM BLOCK/NOAO/AURA/NSF

BENNETT 80 (M12) in Ophiuchus is one of 26 Messier objects Jack Bennett included in his catalog. Novice comet-hunters using small scopes often misidentify globular clusters as comets. M12 measures 16' across and glows at magnitude 6.1.

DANIEL VERSCHATSE

BENNETT 41B (NGC 2997) wasn't in Bennett's original catalog of 130 objects. He added this and 21 others, bringing the total to 152. This magnitude 9.4 spiral galaxy measures 9' by 7' and lies 3½° south of magnitude 4.8 Theta (θ) Antliae.

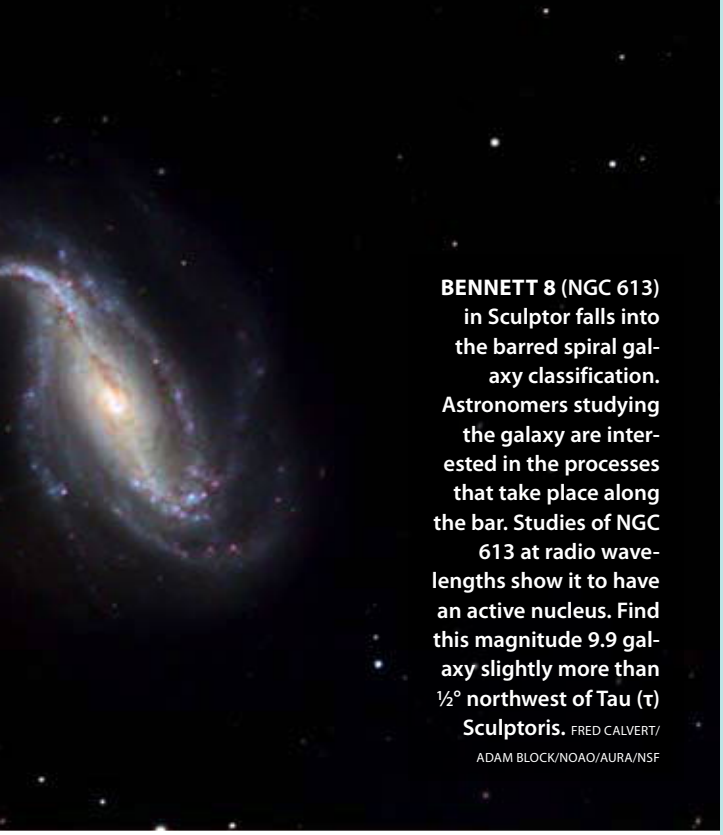
Five years after his first comet discovery, Bennett followed up with another. He recorded: "Comet 1974h was found on 1974 Nov 13 at 3:40 A.M. local time after 17 minutes of sweeping in the first clear morning after more than a week of cloud and rain. The object was in Hydra about 35° above the horizon in the ESE sky. ... My total hours of sweeping since finding comet C/1969 Y1 amount to 482."

Organization

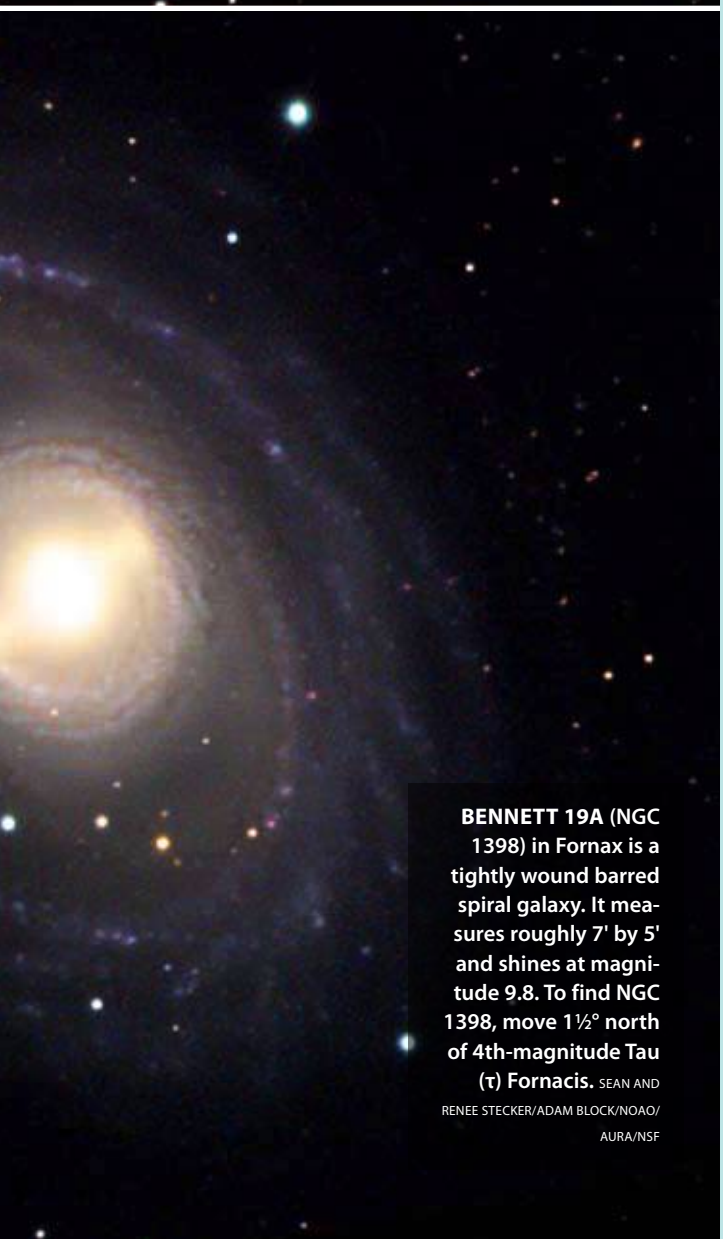
The 152 objects in Bennett's catalog break down into five categories: three bright nebulae, nine planetary nebulae, 24 open clusters, 46 galaxies, and 70 globular clusters. The most northerly object, Bennett 9 (spiral galaxy M77), sits almost exactly on the celestial equator. M77's declination is –0°01'. Bennett 50 (globular cluster NGC 4372) is the most southerly object, with a declination of –72°40'. At magnitude 3.9, the great globular Omega Centauri — Bennett 61 (NGC 5139) — stands out as the brightest object, and Bennett 91a (open cluster NGC 6318 in Scorpius), which glows dimly at magnitude 11.8, is the faintest. Bennett duplicated 26 Messier objects, and, like Messier, who tallied 15 objects in Sagittarius, Bennett also populated that constellation with the most objects — 22.

As the accompanying images show, Bennett incorporated few objects not on most observers "must-see" lists. So, if you find yourself south of the equator, take a look at the objects Jack Bennett chose for his catalog. You won't need a large telescope, and you'll enjoy a tour through the finest objects in the southern sky. A

ONLINE EXTRA Print out the Bennett Catalog at www.astronomy.com/toc.



BENNETT 8 (NGC 613) in Sculptor falls into the barred spiral galaxy classification. Astronomers studying the galaxy are interested in the processes that take place along the bar. Studies of NGC 613 at radio wavelengths show it to have an active nucleus. Find this magnitude 9.9 galaxy slightly more than ½° northwest of Tau (τ) Sculptoris. FRED CALVERT/ADAM BLOCK/NOAO/AURA/NSF



BENNETT 19A (NGC 1398) in Fornax is a tightly wound barred spiral galaxy. It measures roughly 7' by 5' and shines at magnitude 9.8. To find NGC 1398, move 1½° north of 4th-magnitude Tau (τ) Fornacis. SEAN AND RENEE STECKER/ADAM BLOCK/NOAO/AURA/NSF

THE BENNETT CATALOG *Continued from page 79*

Bennett number	Other name	Type	Con.	R.A. (2000.0)	Dec. (2000.0)	Mag.
86	M19	GC	Ophiuchus	17h03m	–26°16'	6.8
87	NGC 6284	GC	Ophiuchus	17h05m	–24°46'	8.9
88	NGC 6287	GC	Ophiuchus	17h05m	–22°42'	9.3
89	NGC 6293	GC	Ophiuchus	17h10m	–26°35'	8.3
90	NGC 6304	GC	Ophiuchus	17h15m	–29°28'	8.3
91	NGC 6316	GC	Ophiuchus	17h17m	–28°08'	8.1
91a	NGC 6318	OC	Scorpius	17h18m	–39°27'	11.8
92	M9	GC	Ophiuchus	17h19m	–18°31'	7.8
93	NGC 6356	GC	Ophiuchus	17h24m	–17°49'	8.2
94	NGC 6352	GC	Ara	17h26m	–48°25'	7.8
95	NGC 6362	GC	Ara	17h32m	–67°03'	8.1
96	NGC 6388	GC	Scorpius	17h36m	–44°44'	6.8
97	M14	GC	Ophiuchus	17h38m	–3°15'	7.6
98	NGC 6397	GC	Ara	17h41m	–53°40'	5.3
98a	NGC 6440	GC	Sagittarius	17h49m	–20°22'	9.3
98b	NGC 6445	PN	Sagittarius	17h49m	–20°01'	11.2
99	NGC 6441	GC	Scorpius	17h50m	–37°03'	7.2
100	NGC 6496	GC	Corona Australis	17h59m	–44°16'	8.6
101	NGC 6522	GC	Sagittarius	18h04m	–30°02'	9.9
102	NGC 6528	GC	Sagittarius	18h05m	–30°03'	9.6
103	NGC 6544	GC	Sagittarius	18h07m	–25°00'	7.5
104	NGC 6541	GC	Corona Australis	18h08m	–43°42'	6.3
105	NGC 6553	GC	Sagittarius	18h09m	–25°54'	8.3
106	NGC 6569	GC	Sagittarius	18h14m	–31°50'	8.4
107	NGC 6584	GC	Telescopium	18h19m	–52°13'	7.9
107a	M24	OC	Sagittarius	18h18m	–18°25'	11.1
108	M17	OC	Sagittarius	18h21m	–16°11'	6.0
109	NGC 6624	GC	Sagittarius	18h24m	–30°22'	7.6
110	M28	GC	Sagittarius	18h25m	–24°52'	6.9
111	NGC 6638	GC	Sagittarius	18h31m	–25°30'	9.2
112	M69	GC	Sagittarius	18h31m	–32°21'	7.6
112a	NGC 6642	GC	Sagittarius	18h32m	–23°29'	8.9
113	NGC 6652	GC	Sagittarius	18h36m	–32°59'	8.5
114	M22	GC	Sagittarius	18h36m	–23°54'	5.2
115	M70	GC	Sagittarius	18h43m	–32°18'	7.8
116	M11	OC	Scutum	18h51m	–6°16'	5.8
117	NGC 6712	GC	Scutum	18h53m	–8°42'	8.1
118	M54	GC	Sagittarius	18h55m	–30°29'	7.7
119	NGC 6723	GC	Sagittarius	18h59m	–36°38'	6.8
120	NGC 6744	Gal	Pavo	19h10m	–63°51'	8.3
121	NGC 6752	GC	Pavo	19h11m	–59°59'	5.3
122	M55	GC	Sagittarius	19h40m	–30°58'	6.3
123	NGC 6818	PN	Sagittarius	19h44m	–14°09'	9.3
124	M75	GC	Sagittarius	20h06m	–21°55'	8.6
125	M72	GC	Aquarius	20h54m	–12°32'	9.2
126	NGC 7009	PN	Aquarius	21h04m	–11°22'	8.0
127	M2	GC	Aquarius	21h34m	–0°49'	6.6
128	M30	GC	Capricornus	21h40m	–23°11'	6.9
129	NGC 7293	PN	Aquarius	22h30m	–20°48'	7.3
129a	NGC 7410	Gal	Grus	22h55m	–39°40'	10.4
129b	IC 1459	Gal	Grus	22h57m	–36°28'	10.0
130	NGC 7793	Gal	Sculptor	23h58m	–32°35'	9.0

Key: Type = Type of object; Con. = Constellation; R.A. = Right ascension; Dec. = Declination; Mag. = Magnitude; GC = Globular cluster; Gal = Galaxy; OC = Open cluster; N = Bright nebula; PN = Planetary nebula

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Astronomy goes Mediterranean

Standing under the Moon's shadow at midday ranks as the greatest thrill nature can provide. /// BY DAVID J. EICHER

▲ ***ASTRONOMY'S*** **eclipse-cruise passengers prepare for the event, waiting for 3 minutes and 53 seconds of totality.** *ASTRONOMY*: DAVID J. EICHER

◀ **THE MOST PICTURESQUE of all Greek islands, Santorini consists of a collapsed volcanic caldera with a city built around one side of the cone. The volcano last erupted in 1950.** *ASTRONOMY*: DAVID J. EICHER

"Read my lips — I guarantee clear weather for tomorrow's eclipse!" So said *Astronomy*'s Senior Editor Michael Bakich in his shipboard talk the day before a total solar eclipse washed over the Mediterranean Sea. Fortunately for Michael — and for the other 700 people aboard M/V *Ocean Monarch*, south of the Greek island of Rhodes — we did, indeed, have clear skies for this magnificent event. *Astronomy* partnered with Astronomical Tours to lead 150 intrepid individuals to a rendezvous with the Moon's shadow.

On March 29, at 1:48 P.M. local time, a brilliant diamond ring appeared and quickly closed to second contact, revealing a huge, flower-shaped corona and a dark total eclipse. Several prominences blazed away to the naked eye, binoculars, and camera lenses everywhere on the ship's top deck. Gasps of "ooh" and "aah" rang out. The ship's captain blew the loud horn, and 3 minutes and 53 seconds of darkness loomed over the sea. Afterward, *Astronomy* readers knew they had witnessed one of the great, emotional events of their lives. A surprising number of passengers were eclipse first-timers. To them, especially, it seemed a magical experience.

Veteran eclipse-chaser David Levy narrated the event, making it even more memorable for first-timers. Venus loomed brightly over the horizon, and Mercury was easy to see midway between the eclipsed Sun and Venus. What a spectacular sight it was! During the ship's voyage, I talked with numerous eclipse-chasers, gave talks, and enjoyed the event with my wife Lynda and 13-year-old son Chris, already a veteran of three total solar eclipses.

Astronomy offered several expeditions to witness this eclipse. The one we took part in spent a week sightseeing in Italy before turning into a Greek island cruise that included eclipse day. The number of astonishing places we saw was staggering.

On March 18, 2006, we arrived in Venice and explored the Doge's Palace, the Campanile (where Galileo demonstrated his telescope in 1610), and the Basilica of San Marco, before taking a luxurious gondola ride down the Grand Canal. On the way to Florence, *Astronomy*'s 150 travelers in Italy stopped at Padua, where we walked the street on which Galileo lived, and Pisa, where we saw the Duomo Cathedral and the celebrated, gravitationally-challenged Bell Tower (the Leaning Tower of Pisa).

David J. Eicher *is the editor of* Astronomy.

AS THE LAST VESTIGE of the Sun's bright disk fades, the reddish chromosphere and numerous small prominences become visible. This marks second contact — the moment totality begins. After second contact, the solar corona blazes into view. JACQUES GUERTIN

PISA'S famous Bell Tower of Saint Mary, known as the Leaning Tower of Pisa, was under construction from 1173–1350. The tower never was supported correctly, and now, its famous lean is preserved carefully by concrete. *ASTRONOMY*: DAVID J. EICHER

ROME'S COLOSSEUM, built by Vespasian, Titus, and Domitian from A.D. 70 to 82, seated about 73,000 spectators for entertainment ranging from gladiatorial games to mock naval battles that took place when the amphitheater was flooded with a special system. Eighty walls radiate from the arena and support vaults, stairways, and seats. *ASTRONOMY*: DAVID J. EICHER

THE WORLD'S best-preserved ancient building, Rome's Pantheon, was built by Hadrian between A.D. 118 and 125.

ASTRONOMY: DAVID J. EICHER

In Florence — the intellectual center of the Renaissance — we saw Bruneschelli's Dome and the tombs of Galileo, Michelangelo, and Machiavelli in the Basilica di Santa Croce. At the Museum of the History of Science, we saw the original lens from Galileo's first telescope and an array of Galileo artifacts including his mummified finger, detached as a relic in 1737.

In Rome, *Astronomy*'s travelers had their most intense 3 days, touring the Basilica of St. Peter and Vatican City, and ancient sites including the Roman Forum, the Colosseum, and Pompey's Theater — the site of Julius Caesar's assassination. In addition, there were the usual tourist spots like the Spanish Steps and the Trevi Fountain.

Our schedule allowed a quick stop at Athens, with a glance at the Acropolis before embarking on our ship. A lovely evening dining at Mykonos preceded a day trip into Turkey to see the amazing ruins of Ephesus, perhaps the best-preserved ancient city from Roman times.

We wrapped up our trip March 30 with a wonderful sunset dinner on the breathtaking cliffs of the Greek isle Santorini. The next day, we returned to the United States exhausted but elated, and now thinking of the next big eclipse! A

EXTRA See Reader gallery on page 102 for more eclipse photos.

{ ECLIPSE JOURNEY, PART 2 }

A Turkish delight

ECLIPSE GLASSES were the eyewear of choice during the early partial phases, but this Turkish mother and daughter have different ideas about their attire. MIKE SIMMONS

HAZE enhances this view of the Fatih Mosque from our Istanbul hotel. MIKE SIMMONS

To the uninitiated, a 10-hour plane ride seems a steep price to pay for 4 minutes of pleasure. But to veteran eclipse-chasers, time and money are minor hurdles in the quest to bask in the Moon's shadow. The March 29 total solar eclipse offered several prime locations for eclipse-viewing, and more than 50 people joined me, my wife Evelyn, and Astronomical Tours for a view from the heart of Turkey.

Our tour began in Istanbul, a city of 13 million with as much hustle and bustle as any big city. Our first full day in Turkey (March 28) was a whirlwind of activity. We toured Istanbul's famous Sultanahmet Mosque (Blue Mosque), Haghia Sophia, and the Spice Bazaar. Yet, as we reveled in the historic sights, we kept a close eye on the weather. Although the skies were clear, a massive front was barreling across Europe and heading for Turkey.

That evening, we flew to Cappadocia — a region in central Turkey best known for conical rock outcrops called fairy chimneys and hidden chapels carved into rocky hillsides. But our group's focus was on the sky. Satellite images showed clouds on the march. The only question was when — not if — they would arrive.

Eclipse morning dawned clear, however, and weather satellites showed the approaching clouds were dissipating. After a few anxious hours, we decided our chosen site in the Göreme Valley should stay clear. Thankfully, the satellites didn't lie.

ISTANBUL'S SPICE BAZAAR offers a colorful, fragrant, and flavorful escape from the bustling city. EVELYN TALCOTT

The site proved to be a spectacular venue for eclipse-viewing. The early afternoon Sun stood halfway to the zenith, perched perfectly above a dramatic series of fairy chimneys. As the sky grew darker, anticipation mounted. Then, a brilliant diamond ring announced the end of the partial eclipse and the onset of totality. The valley erupted with the sounds of unbridled joy as eclipse veterans and novices alike whooped and hollered — and marveled at the intricate detail visible in the Sun's corona. The temperature plunged, falling 16° Fahrenheit (9° Celsius) from late morning to mid-eclipse. After another dazzling diamond ring brought totality to a close, we relaxed and enjoyed a traditional Turkish barbecue prepared by our tour partners in Turkey (FLO–USA).

Although the eclipse marked the trip's highlight, Turkey had much more to offer. We spent the next 2 days exploring Cappadocia. The scenery was magnificent, with fairy chimneys highlighting a landscape of eroded volcanic ash. We also visited several churches dating from the 1st millennium, carved into the rocks so the early Christians could escape Roman persecution.

Then it was off to Pamukkale and neighboring Hierapolis in western Turkey. Pamukkale's claim to fame are impressive white-travertine terraces — layers of calcium carbonate deposited when hot-springs water loses its carbon dioxide. Hierapolis features mineral-rich thermal springs, which made the city a popular spa

Richard Talcott *is a senior editor of* Astronomy.

The Moon and star adorning Turkey's flag made an apt metaphor for watching the Moon eclipse the Sun.

/// BY RICHARD TALCOTT

UÇHISAR CASTLE and its cave houses — many now serving as hotels — rise above Pigeon Valley in Cappadocia. EVELYN TALCOTT

THE TEMPLE OF HADRIAN at Ephesus was built in honor of a visit by Roman Emperor Hadrian in 123. EVELYN TALCOTT

▲ TOTALITY REIGNS for nearly 4 minutes above a series of rocky outcroppings in Cappadocia. The exotic site enhanced the otherworldly quality of the Sun's disappearance. MIKE SIMMONS

in Hellenistic times. Today, the ruins of the ancient city are what draw visitors.

But the epitome of Roman ruins came at our next stop, Ephesus. Founded by Alexander the Great's successor, Lysinachus, Ephesus was the leading port on the Aegean Sea during Roman times. In its heyday, some 300,000 people called Ephesus home. Today, at least that many people each year walk down the stone and marble streets, marvel at the great theater, and sit on the steps of the Library of Celsus.

On our final day in Turkey, we flew back to Istanbul and toured Topkapi Palace. Built by Mehmet II between 1459 and 1465, the palace contains priceless collections of ceramics, silverware, precious stones, arms and armor, and some of the holiest relics of Islam. Topkapi sits on a rise overlooking the Bosphorus, the channel that splits Istanbul between Europe and Asia.

Then it was off to the Grand Bazaar — the world's first shopping mall — teeming with thousands of shops. Truth be told, the constant hawking of merchandise grew tiresome after a week of non-stop activity. But we all figured 2 years should be plenty of time to recharge our batteries and prepare for the next total solar eclipses: a 2-minute arctic adventure in August 2008, and a 6-minute excursion to the Far East in July 2009. Hope to see you there. ▲

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IMAGINOVA.

Canon's EOS 20Da camera sets a new standard for astrophotography. /// BY JACK NEWTON

Designed to shoot the sky

For years, I've wished I could walk

into a camera store and buy a large-chip, single-lens reflex (SLR) camera designed for astrophotography. Now I can. In 2005, Canon introduced a modified version of its 20D digital SLR that's astrophotography-friendly. The latest version, the best-selling EOS 20Da, features a modified infrared-blocking filter that sits in front of an 8.2-megapixel CMOS sensor. The new filter now lets the Hydrogen-alpha (Hα) line of the spectrum, located at the wavelength of 656.28 nanometers, pass through and reach the chip. Capturing this wavelength is a must for high-quality images of many deep-sky objects.

Canon claims this camera captures 2.5 times the Hα light recorded by older models. This means better pictures of emission nebulae. It also boosts an image's overall contrast, an important consideration when shooting faint HII regions.

Other changes help, too. To improve the quality of long-exposure images, the EOS 20Da employs advanced noise-reduction technology. Digital cameras are sensitive to temperature changes, which create optical background noise (seen as white dots) in long exposures.

Mindful of the stars

The Canon 20Da ($1,650 street price) has the conventional features of the better-recognized 20D — you can use it to take family photos and landscapes with perfect color balance. But, for astrophotographers, that's only the beginning.

The best feature may be the sharp, 1.8-inch liquid-crystal display (LCD) on the camera's back. The exposure control also ranks high. It has two settings past bulb: FC1 and FC2. Both lock the mirror and provide instant, real-time focus.

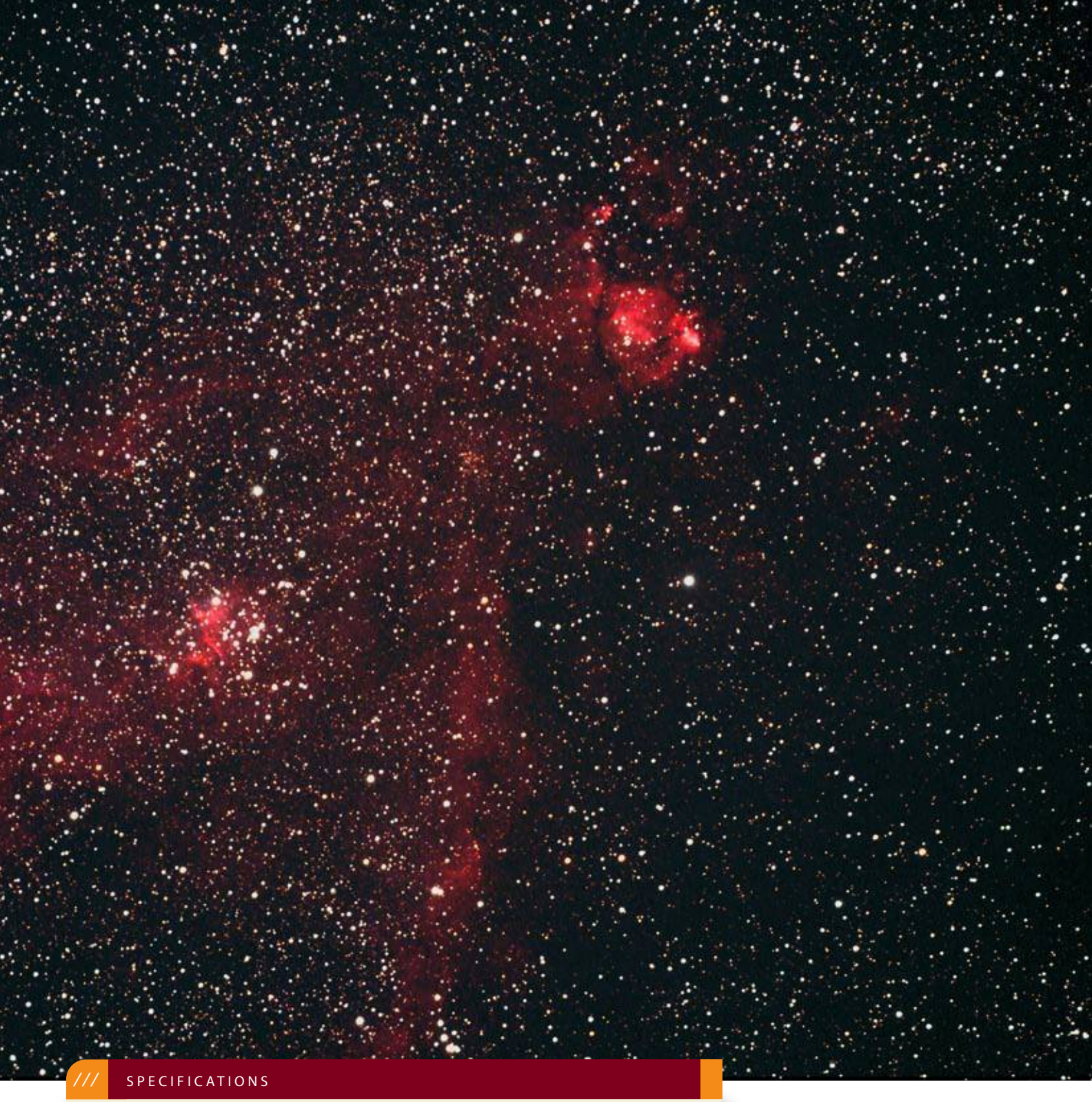
At FC1, you gain a magnification of 5x on the LCD, and, at FC2, the gain is 10x. Higher magnification allows easier focusing of your subject. Be careful using this feature the first few times. At FC1, only 4 percent of the chip's center is active, an area that drops to 1 percent at FC2, so it's important to center your target precisely.

The camera comes with an AC adapter — use this in place of the DC battery for long-exposure sky photos. Canon indicates a fully charged battery should last 2.5 hours

THE CANON 20Da digital SLR employs a special filter that passes more Hydrogen-alpha light than comparable cameras. This results in more detailed images of bright and planetary nebulae.

ASTRONOMY: WILLIAM ZUBACK

Jack Newton *is a world-renowned astrophotographer and manager of Arizona Sky Village, an astronomy community in Portal, Arizona.*



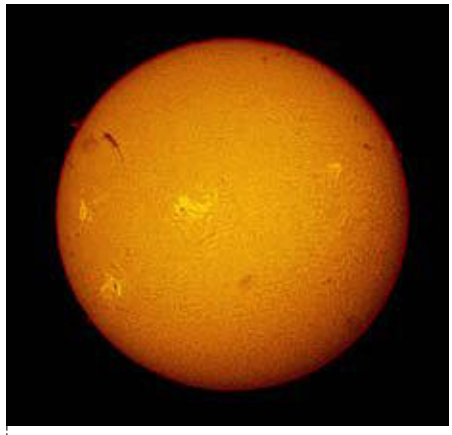
/// SPECIFICATIONS

CANON 20Da DIGITAL SLR

Sensor: High-sensitivity CMOS chip
Image size: 8.5 megapixels (total); 8.2 megapixels (effective)
Maximum resolution: 3,504x2,336 pixels
Interface: USB 2.0 high speed
Viewfinder: Eye-level pentaprism
Shutter speeds: 1/8,000-second to 30 seconds, bulb
Flash: Built-in, auto pop-up
Monitor: 1.8-inch color liquid-crystal
Live-view mode: 5x or 10x monitor magnification
Dimensions: 5.7" by 4.2" by 2.8" (144mm by 105.5mm by 71.5mm)
Weight: 24.2 ounces (685 grams)
Street price: $1,650

FOR THIS IMAGE of emission nebula IC 1795 in Cassiopeia, the author combined fourteen 5-minute exposures at ISO 800. The 20Da's extended transmission of red wavelengths — a result of Canon's modified infrared-blocking filter — brings out this object's deep-red color. JACK NEWTON

THIS 10-MINUTE EXPOSURE of the Milky Way was the author's first nighttime shot through the Canon 20Da. He mounted the camera on the side of his 16-inch Meade LX200 Schmidt-Cassegrain telescope and shot through a 28mm lens set to f/4. JACK NEWTON



JACK NEWTON

SOLAR IMAGES taken through the 20Da revealed Hα detail in the lower chromosphere across the disk and well-defined prominences on the limb. The author set the camera to ISO 200 and shot through a Coronado Maxscope 90 Hα telescope for this 1/250-second exposure.

JACK NEWTON

THE DUMBBELL NEBULA (M27) in Vulpecula posed no problem for the author. This image shows a single 60-minute exposure through a 16-inch Meade LX200 Schmidt-Cassegrain telescope. The author set the 20Da to ISO 800.

in the bulb setting. If you'll be using the camera for long sessions or in cold weather, consider purchasing extra batteries.

Skyshooting

Using instant gratification as my guide, I decided to image the Milky Way for the 20Da's "first light." I set my Canon 10–28mm zoom lens at f/4, focused at infinity, and simply placed the camera on a tripod. That's when I discovered how well this camera delivers. The 20Da's self-timer can take a 30-second exposure on the manual setting. This allows any vibration resulting from handling the camera to dissipate before the shutter opens.

I then attached the camera to my 16-inch Meade LX200 Schmidt-Cassegrain telescope and imaged several objects through it. I combined raw 30-second exposures at ISO 800 I obtained using the self-timer. I used a Coronado Maxscope 90 Hα telescope to test the camera's ability to capture the deep red wavelength of Hα emission; I set the 20Da at ISO 200 for 1/250 second. It performed beautifully. Solar images revealed Hα detail in the lower chromosphere across the disk and showed well-defined solar prominences on the limb. I also imaged the Moon at various phases. The camera's LCD viewfinder made sharp focusing seem almost too easy.

For long exposures, I set the custom-functions menu to FN-02 for noise reduction. This setting causes the camera to follow a regular exposure with a "dark frame" taken for an equal time. The camera then subtracts the dark frame from the first exposure. This dramatically reduces the electronic noise in the final image.

As a focusing test, I chose the great globular cluster in Hercules, M13. I attached the cable release and set the exposure to manual ("M"), ISO to 800, and the shutter speed past B to FC1 to lock the mirror and activate the LCD monitor. I selected the corner star in the Keystone of Hercules nearest to M13. At 3rd magnitude, the star's brightness worked perfectly.

It took about 5 seconds to focus the camera. I activated the cable release, locking the shutter in the open position. Next, I released the cable and moved the shutter speed selector to FC2 — 10x. I refocused, which took only a few seconds, and prepared to take an image. I pointed the telescope toward M13 and checked the centering through the camera's viewfinder. A 5-second exposure provided a razor-sharp image of the cluster. If this camera

JACK NEWTON

A SINGLE 4-minute exposure of the Andromeda Galaxy (M31) revealed lots of detail. For this image, the author set the Canon 20Da to ISO 400.

JACK NEWTON

THIS COCOON NEBULA (IC 5146) wide-field image combined seventy 30-second exposures through a 4-inch Borg 101 refractor. Why so many short exposures? The Canon 20Da has a self-timer and can take a 30-second exposure on the manual setting.

BECAUSE THE 20Da uses interchangeable lenses, a simple T-mount plus a T-adapter allows you to connect it to any telescope. Here, the author mounted the camera on the back of his 14-inch Meade RCX400 telescope. JACK NEWTON

offered only this feature, it would still have been enough to win me over.

Of course, the real test for the Canon EOS 20Da comes when you use it for color astrophotography. Many imagers operate computer-controlled telescopes with CCD cameras. You can control the 20Da directly on such setups (substituting it for the CCD camera) using either a custom RS-232 or serial cable (not provided) or a standard USB 2.0 cable provided with the camera.

Diffraction Limited's camera-control software *MaxIm DL* supports the 20Da through a plug-in. This plug-in allows you to control both the exposure time and ISO settings straight from a computer. Raw files download from the camera as 12-bit RGB images. At this stage, the image appears black and white, but the software then subtracts the dark frame and performs other tweaks to produce the image. *MaxIm DL* activates the color matrix to produce a clean, 16-bit color image.

The Canon 20Da is a high-tech digital imager for the amateur astronomer. Canon has moved the bar up a notch by recognizing the needs of astrophotographers. If the $700 price difference between the 20Da and the regular 20D model is an issue for you, try the relatively inexpensive — but high quality — 8-megapixel 350XT. At less than $1,000, it presents an attractive option for an entry-level digital SLR camera.

Weighing 24.2 oz (685 grams), the 20Da outweighs Canon's Digital Rebel by 7 oz (485g). The higher weight could be a factor if you use a lightweight mount.

But the focus-live LCD makes the 20Da worth every nickel. When I added light-pollution and Hα filters behind the lens, the camera automatically corrected the focus. This feature saved a lot of time.

Astrophotography keeps getting easier, and Canon has made a substantial contribution toward this hobby's enjoyment with the introduction of the EOS 20Da.

/// PRODUCT NOTE

20Da discontinued

On April 10, 2006, Canon announced it would be discontinuing the EOS 20Da as of April 21. The camera debuted in Japan in February 2005, in Europe in June 2005, and in the United States in July 2005. Astroimagers may still be able to purchase the 20Da. Check with reputable dealers, who may have the camera in stock.

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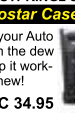

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JULY 28–29, 2006

Stellafane is the largest and oldest

gathering of amateur instrument artisans. The annual event near Springfield, Vermont, which was first held in 1926, gives craftsmen an opportunity to show off their creations and teach telescope-making. ☾ Stellafane is strictly for amateur telescope-makers — vendor displays and the retail sale of commercial products are not permitted. Observing occurs, but is not a primary activity — light pollution from nearby Springfield is too intrusive.

PHIL HARRINGTON

STELLAFANE'S TELESCOPE FIELD will bloom with instruments displayed by proud owners. Participants may enter their scopes into a mechanical or optical competition.

The convention, hosted by the Springfield Telescope Makers, also will feature lectures by prominent astronomers, including comet-hunter David Levy and telescope-innovator John Dobson.

Astronomy Senior Editor Rich Talcott will attend.

For details, e-mail tom@bbso.njit.edu; web site, www.stellafane.com.

JUNE 30–JULY 3

The Great Alberta StarBQ

Eccles Ranch Observatory, near Carlone, Alberta. Located about 2 hours from Calgary, the site offers a clear, dark sky. This is a no-frills star party; participants need to supply their own water and power. For more information, visit www.calgary.rasc.ca/starbq2006.htm.

JULY 16–AUGUST 5

International Astronomical Youth Camp

Tremesek, Czech Republic. This program is for English-speaking students ages 16 to 24 who are interested in astronomy. Each participant will join a research team and develop a project during the camp. For more information, e-mail info@iayc.org; web site, www.iayc.org.

JULY 20–22

Table Mountain Star Party

Table Mountain, Ellensburg, Washington.

Star-party attendance is restricted to 700 people, so register as soon as possible. Guest speakers include David Levy and former astronaut and current Boeing Museum of Flight President Bonnie Dunbar. For more information, visit www.tmspa.com.

JULY 20–22
Weekend Under the Stars
Foxpark, Wyoming. This star party will feature lectures, workshops, and excellent observing. Under a dark sky at 9,100 feet (2,800 meters), some 7th-magnitude stars are visible. For more information, call Martin Curran at 307.635.5944; e-mail, casmail@bresnan.net; web site, home.bresnan.net/~curranm.

JULY 21–23
Gateway to the Universe
Munro Park Family Campground, Powassan, Ontario. This family-oriented star party offers some of the darkest skies in Ontario. For more information, call Merlin Clayton at 705.472.1182; e-mail, galaxy001@sympatico.ca; web site, www.gatewaytotheuniverse.org.

JULY 21–22
Island Star Party
The Victoria Fish and Game Association site, near Victoria, British Columbia. Hosted by the Cowichan Valley StarFinders, this event features observing, lectures, and guided nature walks. For more information, call Frank Ogonoski at 250.748.5110; e-mail, c.v.starfinders@telus.net; web site, starfinders.cvnet.net/home.htm.

JULY 21–30
Summer Star Party
Shady Pines Campground, Savoy, Massachusetts. With unobstructed horizons in all directions, observing should be spectacular. For more information, visit www.rocklandastronomy.com.

JULY 22
Cuyahoga Astronomical Association Annual Convention
Letha House Park, Spencerville, Ohio. The public is welcome at this event. This daylong event will feature observing, workshops, and a potluck dinner. For more information, e-mail, gemmalady@hotmail.com; web site, www.cuyastro.org.

JULY 23–28
Nebraska Star Party
Merritt Reservoir, near Valentine, Nebraska. This is a beginner-friendly star party. Each day begins with a field class that instructs novices in a variety of observing topics. Held near the shore of one of Nebraska's top lakes, the star party offers many other outdoor activities, including swimming, boating, and fishing. For more information, call 402.489.8197; web site, www.nebraskastarparty.org.

JULY 26–30
Mt. Bachelor Star Party
Mt. Bachelor Ski Area, near Bend, Oregon. From an elevation of 5,800 feet (1,787m), the site provides superior naked-eye seeing. This event features observing, workshops, nature talks, and door prizes. For more information, visit www.mbsp.org.

JULY 27–30
Huronia Star Party
Camp Saulaine, near Ivy, Ontario. Daytime activities will include workshops and lectures. At night, volunteers will lead guided tours of the night sky. For more information, visit www.cois.on.ca/~ssaa.

JULY 27–29
Starry Night, Prairie Night
Jeffers Petroglyphs Historic Site, Comfrey, Minnesota. This weekend combines observing, archaeology, and nature. Enjoy a twilight prairie tour to learn about animals of the night. For more information, visit www.jefferspetroglyphs.com. A

CONTACT INFORMATION
Please submit club announcements 5 months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Also use this e-mail address to submit your events for our online calendar.

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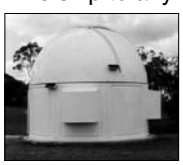

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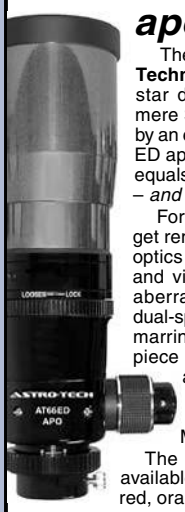
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WIDE-ANGLE ECLIPSE VIEW showing Venus (Nikon D70S digital SLR, 10.5mm fish-eye lens at f/2.8, ISO 400, 1/5-second exposure, taken aboard the M/V *Ocean Monarch* in the Mediterranean Sea) /// **TIM SKONIECZNY, CINTON TOWNSHIP, MICHIGAN**

SOLAR-ECLIPSE IMAGES

Darkness at sea

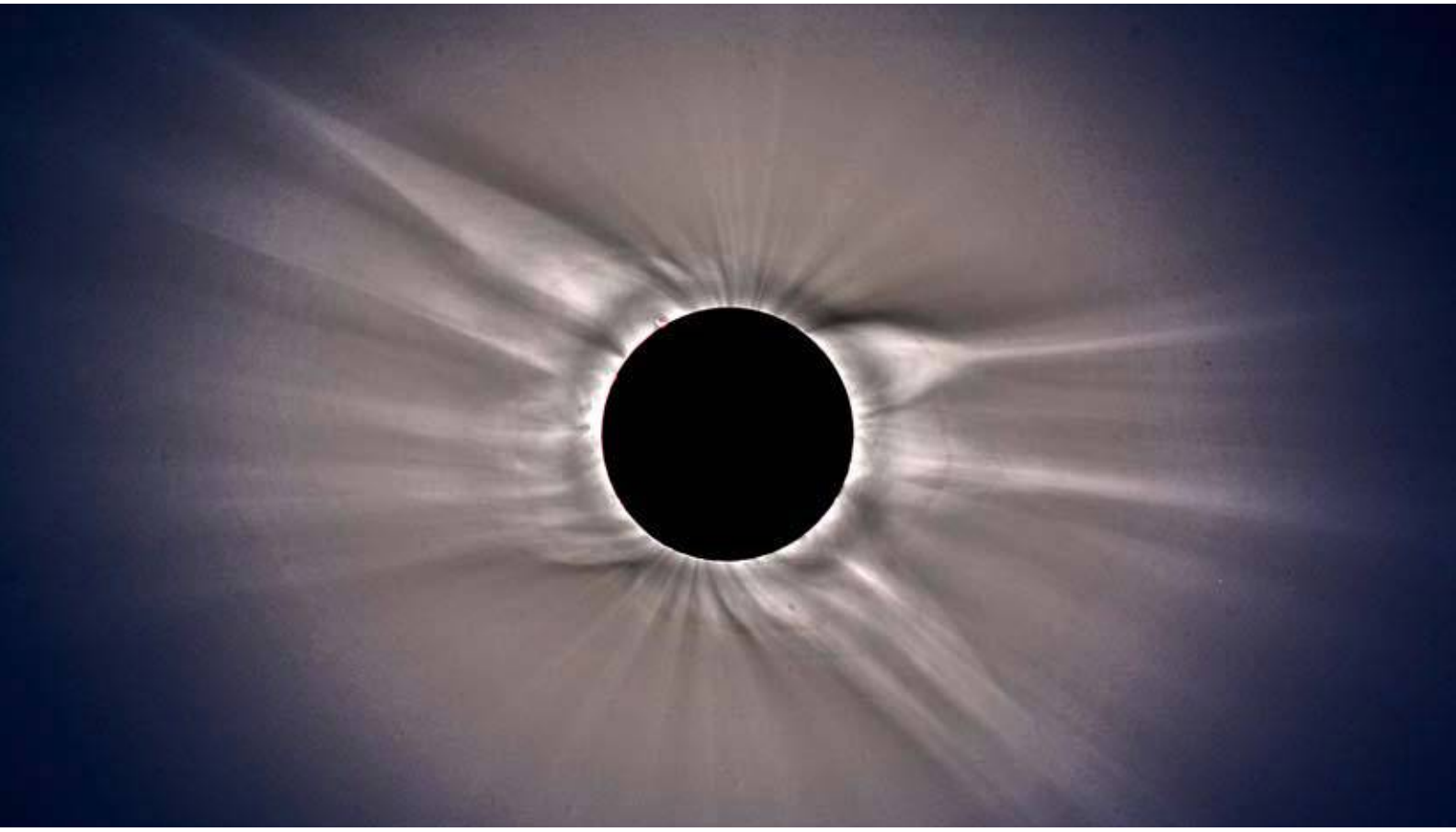
No sight in nature makes such a lasting impression on us as a total solar eclipse. And the drama starts long before the event. Travelers plan trips halfway around the world a year or more in advance. As the day approaches, everyone wonders if they'll be in the right spot and if the weather will cooperate. On March 29, 2006, thousands of eclipse-chasers ventured to Europe and the Middle East to stand under the Moon's shadow at midday. Totality lasted a scant 4 minutes, but the memory will last forever. These images show many of the eclipse's facets, but images are no substitute for being there.

Send your photos to: *ASTRONOMY* Reader gallery, P. O. Box 1612, Waukesha, WI 53187; e-mail to readergallery@astronomy.com.
Please include your full name, date and location of image, and complete photo data: telescope, camera, film, and exposure information.

FIRST CONTACT marks the eclipse's beginning. It occurs when the Moon, traveling eastward, catches up to the Sun and takes the first tiny bite out of its disk. (Canon Rebel XT digital SLR, 500mm Tamron mirror telephoto lens at f/8, 1/1,000-second exposure, taken aboard the M/V *Ocean Monarch* in the Mediterranean Sea) /// **KEN WILSON, MECHANICSVILLE, VIRGINIA**

THE OUTER CORONA extends more than a solar diameter in all directions. This image shows the delicate filamentary structure far from the Sun's disk. (Meade 80mm apochromatic refractor at f/6, Canon EOS 10D digital SLR, ISO 400, 1/45-second exposure, taken aboard the M/V *Ocean Monarch* in the Mediterranean Sea) /// **MIKE REYNOLDS, JACKSONVILLE BEACH, FLORIDA**

"DIAMOND RING!" If you're in a group of eclipse-watchers, it's hard to keep from yelling it. The diamond ring marks the start of totality. (Tele-Vue 85 apochromatic refractor with a 0.8 reducer/flattener yielding f/5.6, Canon EOS 20Da digital SLR, ISO 400, 1/1,600-second exposure, taken aboard the M/V *Ocean Monarch* in the Mediterranean Sea) /// **ADAM CLAYSON, TORONTO**



ALL THE DETAILS in the Sun's corona can't be captured in one shot. Here, the photographer combined multiple images of the corona to bring out more detail. This image of the 2006 eclipse, more than any other, comes closest to showing what the human eye saw during totality. (Canon 5D digital SLR, Canon 300mm IS L lens at f/16 plus 2x tele-extender, ISO 200, exposures range from 1/125-second to 4 seconds, taken near Salum, Egypt) /// **CHARLEY MANSKE, WATSONVILLE, CALIFORNIA**

THE ANATOMY of second contact shows a 30-second sequence that begins after the first diamond ring. After the ring's brilliance faded, observers saw a few red prominences. (Canon 5D digital SLR, Canon 300mm IS L lens at f/16 + 2x tele-extender, ISO 200, exposures range from 1/1,000-second to 1/125-second, taken near Salum, Egypt) /// **CHARLEY MANSKE, WATSONVILLE, CALIFORNIA**

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